Revised.

U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 52.

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THE SUGAR BEET:

CULTURE, SEED DEVELOPMENT, MANUFACTURE, AND STATISTICS.

BY

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U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF CHEMISTRY,
Washington, D. C., February 7, 1899.

SIR: I have the honor to transmit herewith the manuscript of the revised edition of Farmers' Bulletin No. 52.

The subject-matter of this bulletin remains practically the same as in the original edition. It was found necessary to revise the statistical part, however, and to bring it up to date.

It is hoped that in its new form this bulletin may prove as beneficial as its predecessors in directing the interest which is being manifested in the culture of the sugar beet and in the manufacture of sugar therefrom into reliable channels of experiment and investigation. This edition makes the total number of copies of this bulletin which have been issued 200,000, and the demand for it seems to be undiminished.

Respectfully,

H. W. WILEY, *Chemist.*

Hon. JAMES WILSON,
Secretary of Agriculture.

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THE SUGAR BEET.

INTRODUCTION.

Among the farmers of the country there is in general an erroneous opinion respecting the manufacture of beet sugar, especially concerning the cost of a factory. It is well that our farmers should cherish no illusions in regard to this matter. The manufacture of beet sugar is an industry entirely distinct from agriculture, and can only be successfully accomplished by the investment of large capital under the direction of skilled artisans. From the nature of the process, it is quite improbable that any simple method of home manufacture of beet sugar will ever prove commercially successful. The juices of the beet are extracted with difficulty. They contain large quantities of mineral salts which render the crude sugar and molasses made therefrom bitter and unpalatable. Simple processes for the extraction of the juice can at best remove only from 60 to 70 per cent of the sugar which the beet contains, and thus a percentage of loss is incurred which at the very outset renders it impossible for a home apparatus to compete with a large factory. Beet sugar, for the reasons given above, can not be used in the raw state, as is the case with the products derived from the sugar cane, sorghum, and the maple tree. The refining of the sugar is a process which requires an expensive outlay for machinery and a high degree of supervisory skill. It can not therefore be accomplished upon the farm. The various schemes which have been proposed whereby the farmer is assured of the possibility of preparing a crude product to be subsequently shipped to a central refinery are not practicable on account of the radical difficulties above outlined. The low prices at which sugar is sold render imperative in the process of manufacture the most economical methods, which are only made possible by the use of improved machinery operated under the direction of technical experts. The farmers of this country, as is the case with those of Europe, in respect of the beet sugar industry, must be satisfied with acquiring the requisite degree of agricultural skill to produce a crop of beets with a paying tonnage and a high content of sugar.

One of the remarkable facts shown by the statistical tables in this bulletin is found in the information they contain showing that the sugar beet has been able on demand to supply the remarkable deficiency in the world's sugar crop produced by the Cuban war. In three years the supply of sugar furnished by that island has fallen from 1,000,000 to

about 100,000 tons, and yet there has been no appreciable deficit noticed in the total sugar production of the world.

The remarkable opportunities for the extension of profitable agricultural industries in this country, through the medium of the sugar beet, should not be suffered to pass unimproved, and the farmers of our country should not rest satisfied until they see our own fields produce the sugar which we consume.

CLIMATIC CONDITIONS AFFECTING THE GROWTH OF THE SUGAR BEET.

Experience has shown that the sugar beet reaches its highest development in north temperate latitudes. So far as the production of beets with high tonnage is concerned, it is found that this can be accomplished far to the south, but beets grown in such localities are, upon the whole, less rich in sugar and less suitable for the manufacture of sugar than those grown farther north. It must be remembered, however, that the expressions north and south do not refer to any absolute parallels of latitude, but rather to isothermal lines, which in many cases run obliquely to the parallels of latitude and in some cases cross them almost at right angles. As a result of many years of careful experimentation, it may be said that as far as temperature alone is concerned the sugar beet attains its greatest perfection in a zone of varying width through the center of which passes the isothermal line of 70° F. for the months of June, July, and August. This zone for this country is shown in the accompanying map (fig. 1).

THE THEORETICAL BEET-SUGAR BELT OF THE UNITED STATES.

This isothermal line, for the United States, begins near the city of New York and passes up the Hudson River to Albany; thence turning westward, it runs near Syracuse and passes in a southwesterly direction, touching the shore of Lake Erie near Sandusky, Ohio; turning then in a northwesterly direction, it enters Michigan and reaches its highest point in that State near Lansing; then going in a southwesterly direction, it enters the State of Indiana near South Bend, passes through Michigan City, then in a northwesterly course continues through the cities of Chicago and Madison, reaching its highest point near St. Paul, Minn. Thence it extends in a southwesterly direction until it enters the State of South Dakota, where it turns again northwest and reaches its highest point in Dakota just above the forty-fifth parallel of latitude, where it crosses the Missouri River. The isothermal line then turns almost due south, following very closely the one hundred and first degree of longitude until it leaves the State of Nebraska near the northeast corner of Colorado; passing in a southwesterly direction through Colorado, it reaches, at Pueblo, almost to the one hundred and fifth degree of west longitude, whence it passes in a slightly southeasterly direction into New Mexico, turns to the west, and crosses the one

hundred and fifth degree of longitude and about the thirty-second degree of latitude. Then turning westward, it passes in a very irregular line through the States of California, Oregon, and Washington.

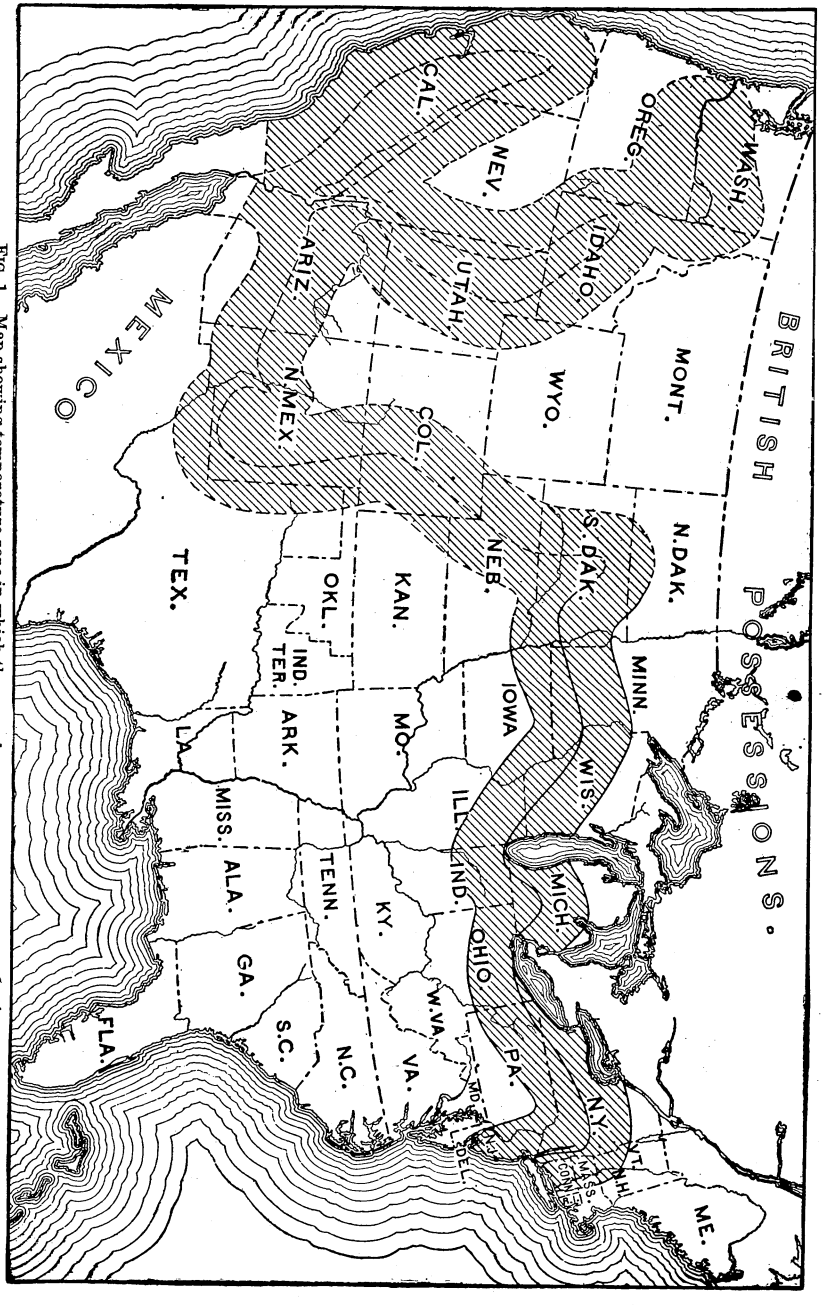

FIG. 1.—Map showing temperature zone in which the sugar beet attains its greatest perfection.

Extending a distance of 100 miles on each side of this isothermal line is a belt which, for the present, may be regarded as the theoretical beet-sugar area of the United States. There are doubtless many localities lying outside of this belt, both north and south, in which the sugar beet will be found to thrive; but this will be due to some exceptional qualities of the climate or soil and not to any favorable influence of a higher or lower temperature. A mean temperature of 70° F. in the summer, however, must not be regarded as the only element of temperature which is to be taken into consideration. In those localities where the winters come early and are of unusual severity will be found greater difficulties in the production of sugar from the sugar beet than in those localities where the winters are light and mild, although the mean summer temperature of both localities may be represented by 70° F. As an illustration of this difficulty may be cited northern Nebraska and South Dakota, where the winters are of great severity, and southern California, where there is scarcely any winter at all.

The mean summer temperature of these localities is about the same, but the continuation of a semisummer temperature through the winter in southern California greatly favors the growth and manufacture of the beets. In northern Nebraska and South Dakota the beets, which are to be manufactured during the winter time, have to be protected by expensive silos. In southern California and other places similarly situated the beets can be protected without any covering, or at most with only a slight covering of leaves or straw. The season for planting in a mild climate is also longer. For instance, in southern California planting can commence as early as January and continue till June, thus giving a beet crop coming continuously into maturity from the 1st of August to the 1st of December. In other localities the planting must be accomplished in a short time, say from the 10th of May till the 1st of June. Before the first of these dates the ground will be too cold for planting and after the second the season will be so late as to prevent the maturity of the beets before frost. When the field is properly plowed and subsoiled in the late autumn the farmer will be able to take advantage of the first favorable opportunity in the spring to prepare the surface of the soil and plant the seed.

CONDITIONS OF PRECIPITATION.

Although conditions of temperature must be taken into consideration in selecting sites for beet-sugar factories, yet in addition to the thermal conditions must also be studied those of rainfall. The sugar beet requires a certain amount of moisture in order to produce its normal crop. This moisture must be derived either from precipitation in the usual way, by irrigation, or else the soil must be of that particular quality which will allow subterranean moisture to reach the rootlets of the plants. Soil of this latter kind appears to exist in many localities in California, where beets are grown almost without rain. The porous

and sandy soils adjacent to many of the Western rivers, such as the Platte River in Nebraska and the Arkansas River in Kansas, also appear to furnish a sufficient amount of subterranean moisture to produce a good crop in connection with the rainfall, of which, however, but little is expected in those localities during the summer months. Where there is little subterranean moisture, and where irrigation is not practicable, the endeavor should be made to secure localities for the growth of the sugar beet where an average summer precipitation of from 2 to 4 inches per month may be expected. There are many conditions of agriculture, however, under which the beet becomes quite independent of extremes of precipitation. The beet may thrive with very little rainfall or with a great deal, if properly cultivated in a suitable soil.

GROWTH OF BEETS ON IRRIGATED LANDS.

The experience of more than ten years in California has shown that the climatic data, regarded as of prime importance in beet culture in Europe, can not be regarded as rigidly applicable to this country. The successful growth of sugar beets in the arid regions of our country, with and without irrigation, has introduced a new factor into the science of beet meteorology. While the arid area on which beets can be grown without irrigation is probably confined almost exclusively to the coast valleys of California, the successful commercial production of sugar beets in Utah and New Mexico has opened up a new and extensive field for the extension of the sugar industry over large areas suited to irrigation in the western and southwestern regions of the United States. It is certain now that Colorado, Utah, New Mexico, Idaho, and Arizona may become great sugar-producing States, not excluding other areas in the arid region. California has already set the pace of progress, and the other arid States will not be slow to follow. The high cost of good irrigation renders it imperative that the areas under culture be devoted to a crop which is capable of producing a more valuable yield than is afforded by cereal culture. Of all the home markets for our domestic agricultural products, there is none so insistent nor so expansive as that for sugar. With an annual consumption of 2,000,000 tons, and with a certainty of rapid increase, the demand for sugar promises to be the salvation of American agriculture.

The northern parts of our Eastern and Middle States and the States of Oregon and Washington have at least an equal chance for the successful production of beet sugar with the fields of Germany and France. The irrigable parts of the great Southwest, it is believed, have advantages of soil and climate which will enable them to enter into competition even with the Hawaiian Islands and Cuba. To be able to control the moisture in the soil is a matter of prime importance to the beet grower. In the arid region the beet can be left to mature at the proper time by withholding the water. Subsequently there is no danger of loss due to second growth, so easily induced by late warm autumnal

rains. In a dry soil the beet can endure without damage a low temperature, which would prove quite disastrous in a wet climate. More complete maturity may be thus obtained, and a more leisurely harvest. In fact, there is no staple crop which can compete with the sugar beet in demanding the favorable attention of those interested in irrigation. If a net profit of from $10 to $20 per acre can be secured, from $100 to $200 per acre can be paid for the land. It is estimated that nearly 100,000,000 acres of land in the arid regions of the United States may eventually be irrigated, being nearly one-fifth of the total area. Of this area perhaps 10 per cent are capable of easy and speedy irrigation. One million acres planted to beets would yield, under intensive culture, a quantity of sugar sufficient, with the Louisiana product, for domestic consumption. There is nowhere in sight a more promising prospect for agricultural development than in the production of sugar beets on irrigated lands.

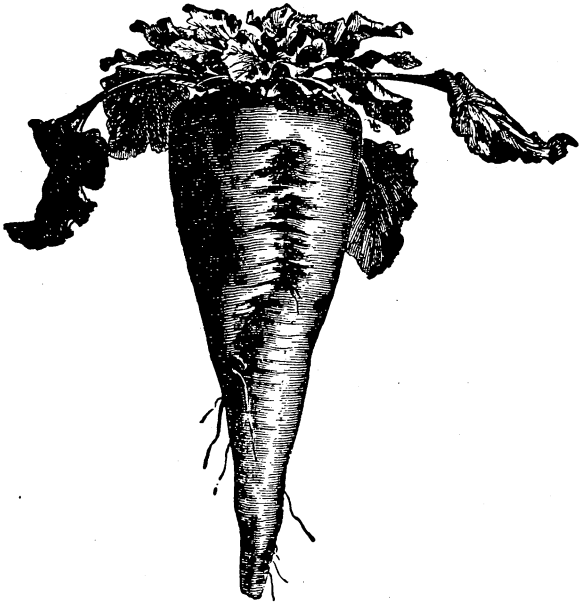

FIG. 2.—White Improved Vilmorin Sugar Beet.

VARIETIES OF BEETS.

All kinds of sugar beets are botanically identical with the common garden beet, *Beta vulgaris*. The differences in varieties have arisen by reason of special selection and culture, producing a pure strain of some valuable peculiarity in the beet. These accidental valuable qualities, by careful selection, have become fixed, and are associated with certain external properties which have thus come to be regarded as distinguishing characteristics.

The shape and size of the beet, its color, the character of the foliage, whether erect or spreading, etc., are the most frequent marks of distinction. The beets are also frequently designated by the names of those who have developed them, by the name of the town or locality in which they have been grown, or by their color.

Among the more frequently occurring varieties grown in Europe may be mentioned the Vilmorin Improved, Kleinwanzlebener, Improved Kleinwanzlebener, White Excelsior, White Imperial, Simon Le Grande, Florimond and Bulteau Desprez Richest, Brabant Sugar Beet, Rose Imperial, Demesmay, etc.

The two varieties which have been most widely grown in this country

are the Vilmorin Improved and the Kleinwanzlebener. The certainty that the seed has been grown according to the most scientific methods is of greater importance to the beet grower than the variety. The beet has reached such a high state of perfection as to make the least degree of laxity in its treatment exceedingly dangerous to its qualities.

The general type of the Vilmorin Improved is illustrated by fig. 2. This beet is the result of thirty-five years of methodic and persevering selection based upon the lines to be indicated hereafter. In regard to its preservation, it is recognized that it holds its sugar content better than any other variety. In those factories in which the Improved Vilmorin is manufactured in connection with other varieties, it is the custom to reserve this variety for the end of the season and to work up the less reliable beets at an earlier date. It is also said to resist better than any other variety the unfavorable influence of certain characters of soil and of certain manures. In black soils, rich in organic matter, it gives great industrial results, while most other varieties of beets become watery or saline in excess.

FIG. 3.—Kleinwanzlebener Sugar Beet.

Excessive quantities of nitrogenous fertilizers, which are carefully excluded from ordinary varieties, can be applied with safety to the Improved Vilmorin, as a great number of experiments has shown that this can be done without serious deterioration in the quality of the sugar and with a considerable increase in weight. From thousands of analyses it has been established that the percentage of sugar which can be obtained with this variety is about 16. Its average yield under favorable conditions can be stated to be from 12 to 16 tons per acre.

Perhaps more important for general cultivation than the Vilmorin variety is the beet known as the Kleinwanzlebener, which at the present time has probably a wider cultivation than any other sugar beet. The general character of this beet is shown by fig. 3.

This beet has a conical root, straight and even, quite large at the head and rapidly tapering. It is distinguished from the Improved Vilmorin by its brighter color and its lighter colored leaves, which are beautifully undulating or scalloped about the edges. Coming from a cross in which the Improved Vilmorin entered largely, the Kleinwanzlebener is to-day a fixed variety and is equally well produced in France and Germany. It succeeds in soil of an alluvial nature and average richness and on level plateaus. In soils very rich in humus it ripens poorly and loses much of its richness. Like the Vilmorin Improved, toward the end of vegetation its leaves are completely spread. In those conditions of culture where the Improved Vilmorin gives from 12 to 16 tons per acre, the Kleinwanzlebener gives from 14 to 18 tons. It is, however, generally inferior to the Vilmorin Improved in saccharin richness, which the whiter and more watery appearance of its flesh would make known at first view. Nevertheless, from 13 to 15 per cent of sugar can be obtained in the beet in field culture.

FIG. 4.—Brabant Sugar Beet.

The Brabant sugar beet is altogether different in aspect from the preceding varieties. It is long, rising well above the level of the soil, and carries a foliage vigorous in growth and upright in position. This variety would seem at first view to have come from the white varieties

used for forage; nevertheless, its great vigor, its abundant production, and its sufficiently high content of sugar make it a beet quite valuable in those countries where the tax is placed upon the amount of sugar made rather than upon the beet. The Brabant sugar beet will give easily 20 tons per acre, and may be made to contain 12 per cent of sugar. Its general appearance is shown by fig. 4.

In France the adoption of legislation placing the tax upon the beet itself has not entirely banished the Brabant variety, but it has succeeded in transforming it into one of greater richness in sugar. This variation of the Brabant beet has been called the French Rich Sugar Beet, and seems destined to have a brilliant future, preserving in its general aspect, and notably in its foliage, many of the characteristics of the Brabant. The French Rich Sugar Beet differs distinctly from the Brabant in the fact that it grows entirely under the soil, is more slender, has a ruddier skin, and more compact flesh. Its yield is superior to the Vilmorin Improved and equal to the Kleinwanzlebener. The content of sugar of this new variety is rarely inferior to 14 per cent. Its general appearance is shown by fig. 5.

FIG. 5.—White French Rich Sugar Beet.

The Imperial sugar beet is one which is largely grown throughout Europe. It has a regular conical outline, with oval-shaped top, and its leaves have rather short stems. There are different varieties, such as the Old Imperial, Improved White Imperial, and the Improved Rose Imperial. Other varieties of beets largely grown are the Electoral,

the Improved Elite, the Improved Imperial Elite, the Imperator, Olive Shaped, the Excelsior, etc.

Following are the names of some of the firms producing high-grade beet seed of the above-named and other varieties in Europe:

Vilmorin, Andrieux & Co., Paris.
Dippe Bros., Quedlinburg, Germany.
Carl Schobbert & Co., Quedlinburg, Germany.
Desprez, Père et fils, Cappelle, par Templeuve (Nord) France.
G. Schreiber & Son, Nordhausen, Germany.
Klein & Soukoffsky, à Bielany, Poste Beresovka, Podolien, Russia.
S. L. Ziemann, Quedlinburg, Germany.
Otto Breustedt, Schladen-am-Harz, Germany.
F. Demesmay, Cysoing (Nord), France.
Schlitte & Co., Aumühle bei Gorsbach, Germany.
H. Hornung & Co., Frankenhausen, Germany.
Heinrich Mette, Quedlinburg, Germany.
C. A. F. Degering, Quedlinburg, Germany.
Ladislaus Mayzel, Brzozówka, Post Stopnica, Russian Poland.
Martin Grashoff, Quedlinburg, Germany.
Adolph Strandes, Rittergut Zehringen bei Cöthen (Anhalt), Germany.
Association Maurus Deutsch, 8 Rue Lafitte, Paris.
M. Knauer, Gröbers, Saxony, Germany.

In this country considerable quantities of beet seed have been grown by the Alameda Beet Sugar Company, of Alvarado, Cal., chiefly for its own consumption. It is probable that there are other growers of beet seed in this country, but no definite information concerning that point can be given.

SOIL.

The sugar beet does not require a particular kind of soil for its proper production. In general, soils are described for practical purposes as clayey, sandy, loamy, or alluvial soils; all of these soils will produce beets. The black prairie soils also have been found, with proper cultivation, to produce excellent beets. Perhaps the best soil may be described as a sandy loam; a soil containing a happy equilibrium between organic matters, clay, and sand.

In general it may be said that any soil which will produce a good crop of Indian corn, wheat, or potatoes will, under proper cultivation, produce a good crop of sugar beets. The soil on which sugar beets are grown, however, should be reasonably level, and this being the case it should be well drained. Natural drainage on level soil being somewhat deficient, it is advantageous that tile drainage be practiced. It would be difficult to grow sugar beets on level land without good drainage, especially in a rainy season.

FERTILIZATION.

Happily, in most American soils there is still sufficient natural fertility to produce a good crop of sugar beets; whereas in the soils of Europe, where sugar beets have been grown for years, the farmers must depend on fertilizers to insure a remunerative crop.

Two kinds of fertilizers are employed: stall manure from the farm, and artificial manure generally known as commercial fertilizers. For general purposes, stall manure is desirable. It should be applied, in a well-rotted condition, in the autumn before the ground is plowed. The quantity per acre depends, of course, on the fertility of the soil; but in any case it is not best to apply a very heavy dressing. In poor soils it is best to apply the fertilizer for several years in succession, rather than to apply enough at once to bring it up to the required state of fertility. Too copious an application of stall manure is apt to produce overgrowth in the beets, which makes them ill suited to the manufacture of sugar. If the fertilizer be applied in an unrotted condition, it is apt to seriously injure the crop in case of dry weather.

Of commercial fertilizers three classes are employed containing, respectively, nitrogen, phosphoric acid, and potash. In some instances these three elements are found combined in the same commercial fertilizer. Nitrogenous manure should be applied with great care to sugar beets. It tends to produce a very heavy growth of the beet, and thus to diminish its content of sugar. Potash and phosphoric acid can be applied with great freedom to beet fields; in general they act much better in conjunction than when applied separately.

The principles of fertilization depend upon the fact that a soil of good quality should have returned to it all that the harvest has removed, and a poor soil be supplied with those elements in which it is deficient.

Nothing can be more certain than that a soil to which this restoration is not fully made will gradually lose its faculty to produce plants in normal quantity and composition. Culture experiments with artificial liquid manures have not been carried so far with the beet as with some other plants, and therefore the dependence between the composition of such liquids and the evolution of the beet has not yet been determined. The basis is also wanting whereon the direct working of the manure on the beet can be predicted; and here is met the well-known difficulty of getting the manures into those layers of the soil from which the beet chiefly draws its supplies of mineral plant foods.

PRECAUTIONS TO BE OBSERVED IN APPLYING STABLE MANURE.

Since experience has taught that beets raised on fields freshly fertilized with stable manure are inferior for purposes of manufacture, the rule has long been established that not the beets, but the previous crop should be fertilized with this material, or that the beets should be raised in rotation as the second or even third crop. Unfortunately this rule, so important to the factories, is not always observed, and as a consequence of heavy manuring large crops have been produced, but at the cost of diminished sugar content or lessened price. This rule applies especially to stable manure and night soil, as well as to Chile saltpeter, the misuse of which has produced such serious consequences for factories, but not to phosphatic manures, which usually exert a favorable influence upon the crop.

QUANTITIES OF PLANT FOOD REMOVED FROM THE SOIL.

The constituents to be taken into account in the necessary restitution to the soil of the elements removed by beets are potash, phosphoric acid, magnesia, and nitrogen. Following are the quantities of these constituents in 1,000 pounds of beets and beet leaves, determined by numerous analyses:

Constituents.	Roots.	Leaves.
	Pounds.	*Pounds.*
Potash	3.3	6.5
Phosphoric acid	0.8	1.3
Magnesia	0.5	3.0
Nitrogen	1.6	3.9
Total ash	7.1	18.1

It will be seen from the relation between the roots and leaves that for equal weights the amounts abstracted by the latter are considerably greater and deserve especial consideration in case the leaves are used for cattle food. From this point of view the leaves should be left in the field. It is certain that otherwise complete restitution is attended with some difficulty. The form in which the above-mentioned plant constituents shall be returned to the soil is well established for phosphoric acid and magnesia, and partly for nitrogen. Superphosphates, with greater or less content of phosphoric acid, or with addition of a nitrogenous element, and basic phosphatic slags, are of universal application. As has been shown by direct investigations, the magnesia is nearly all returned in the press cakes from the factory, though a more uniform distribution than is thus secured is much to be desired.

The soil ingredients most essential for the successful production of sugar beets are nitrogen, phosphoric acid, potash, lime, and magnesia.

Most soils contain a sufficient quantity of magnesia, and the press cakes from the factory, which should be returned to the soils, will supply any deficiency. The same is true in regard to lime, although there are some soils in which the supply of lime is naturally deficient. Such soils would be benefited by an application of land plaster, burned lime, phosphatic slags, or ground shells. Phosphoric acid and potash are supplied in the form of ordinary commercial fertilizers: the phosphorus as ground bone, superphosphate, and basic slag; and the potash as kainite or other salt. Of the various potash compounds found in natural deposits, all are useful. Preference is due only to compounds with organic substances. Consequently the molasses, or its residue after distillation, and the liquors of the molasses working processes, all rich in potash, are themselves very valuable materials for potash fertilization, and should be carefully preserved for such use. It must not be supposed, however, that the demand for potash will be satisfied by returning to the soil the molasses from the crop of beets in the form of waste products. Aside from the leaves, for which if taken from the field a largely increased potash return must be made, the molasses itself does

not represent the entire amount of potash taken. Factories which produce raw sugar sell with it also potash, and in all factories the waste waters carry away potash compounds sufficient to account for the difference between the amount of potash in the beets and in the molasses.

Phosphoric acid is best supplied in the form of ground bone, superphosphate, or basic slag from steel factories.

Nitrogen may be supplied in the form in which it exists in ground bone or from the refuse of the slaughterhouses in the form of dried blood and tankage, or as cotton-seed meal or oil cake, or as nitrate of soda, sulphate of ammonia, etc. The simultaneous application of stall manure and nitrate of soda is not advisable by reason of the possible loss of nitrogen due to the development of denitrifying ferments.

As to the relation which the quantity of material returned to the soil should bear to the quantity abstracted by the beet it may be said in general that it is desirable to return as much nitrogen, from one and a quarter to one and a half times as much potash, and two and a half times as much phosphoric acid as have been removed by the roots. Greater additions of potash and phosphoric acid have no disadvantageous effects upon the crop. Direct investigations in regard to the relation between the sugar and potash in consecutive crops for many years have failed to give the least ground for a contrary conclusion. But it must not be expected, on the other hand, that increasing fertilization, especially potash fertilization, will produce proportionately increasing crops, as has been asserted by some.

EFFECT OF NITROGENOUS MANURES ON THE QUALITY OF THE BEET.

The opinion has generally prevailed among beet growers during late years that heavy nitrogenous manuring, especially with nitrate of soda, produces no injurious effect on the quality of the beet. This opinion was based on the fact that in such beets the sugar per cent was only slightly diminished. Nevertheless the quality of a beet may be impaired even with little or no diminution of the sugar content by reason of the increase of the percentage of nonsugars present.

In this respect it has been shown that heavy manuring with nitrogenous substances greatly injures the quality of the beet for sugar-making purposes. The apparent coefficient of purity of the juice is also frequently misleading, since no account is taken of the nature of the nonsugars present.

The real purity of the beet is also to be distinguished from the apparent purity of the juice. The real purity of the beet is obtained by dividing the percentage of sugar in the beet by the total solid matter in solution therein; the apparent purity of the juice by dividing the percentage of sugar therein by the apparent percentage of solids as indicated by the specific gravity. Judicious fertilizing with nitrate of soda, however, is beneficial, and this form of nitrogenous fertilizer is in many respects the best known for beets.

ROTATION.

Beets do best after wheat or some other cereal. It is true that soils on which beets have not been grown, as the soils of this country, may produce beets for several years without harm. Nevertheless, proper rotation is always desirable.

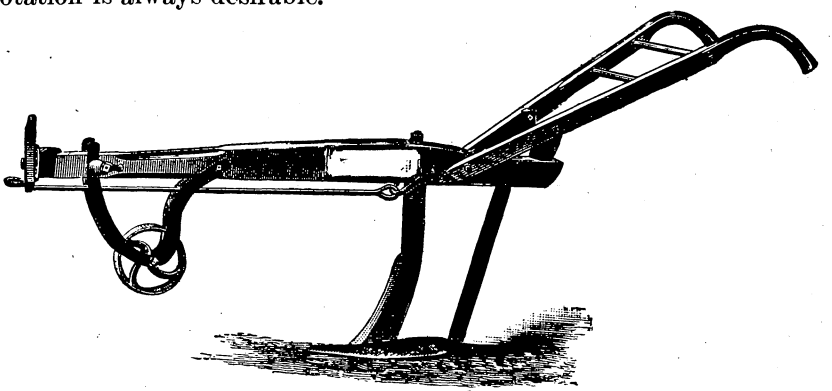

FIG. 6.—Subsoil plow.

A good scheme of rotation is, first, wheat; then beets; then clover, one crop of which is cut for hay and the second crop plowed under; then potatoes, wheat, and beets in the order mentioned. By this method, and a judicious use of stall manure and commercial fertilizers, the fertility

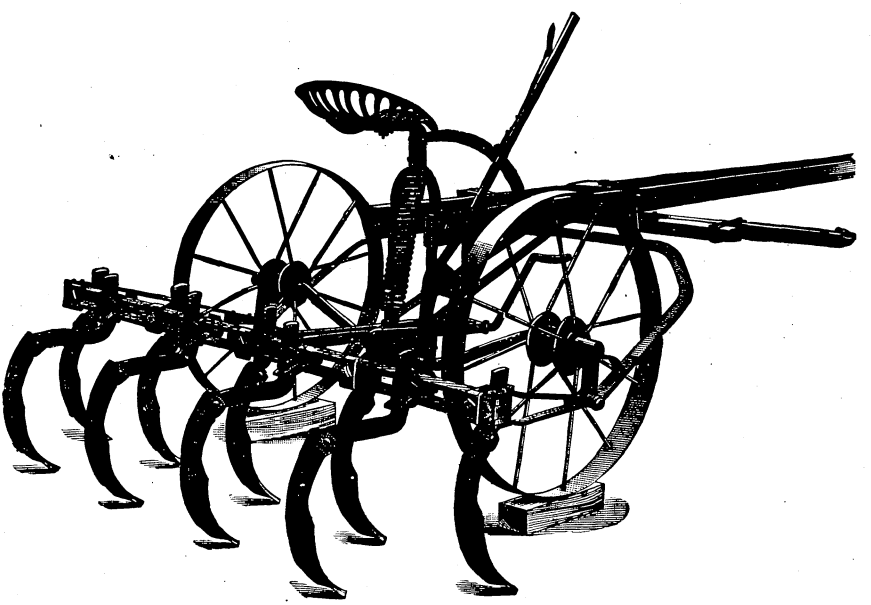

FIG. 7.—Cultivator.

of the soil can be maintained and even increased. Beets should follow wheat or other cereal crop, because this crop, being harvested early, leaves the ground ready for late autumn plowing, a prerequisite to successful beet culture.

PREPARATION OF THE LAND FOR PLANTING.

The field in which beets are to be planted should be selected and plowed in the late autumn to the depth of at least 9 inches. The plow in each furrow should be followed by a subsoiler, which will loosen the soil

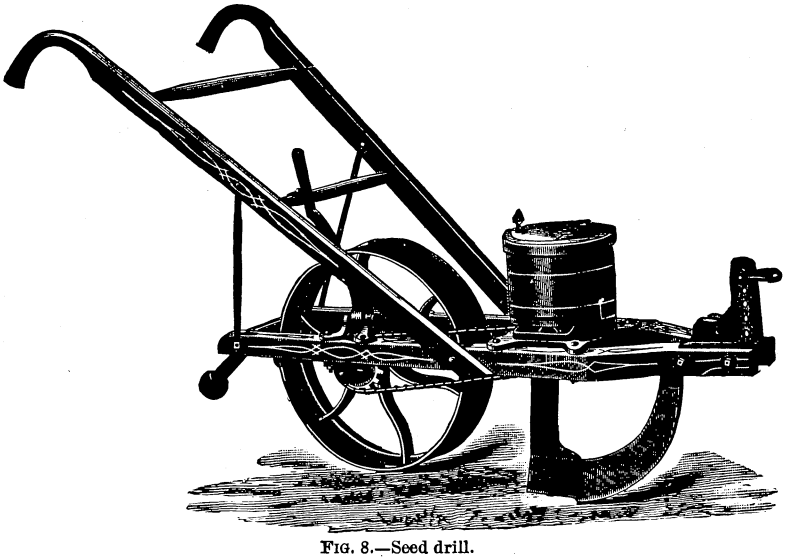

FIG. 8.—Seed drill.

to the depth of 6 or 7 inches more. A convenient subsoil plow is shown in fig. 6. Each field to be planted in beets should thus have the soil prepared by thoroughly loosening it to the depth of from 15 to 18 inches.

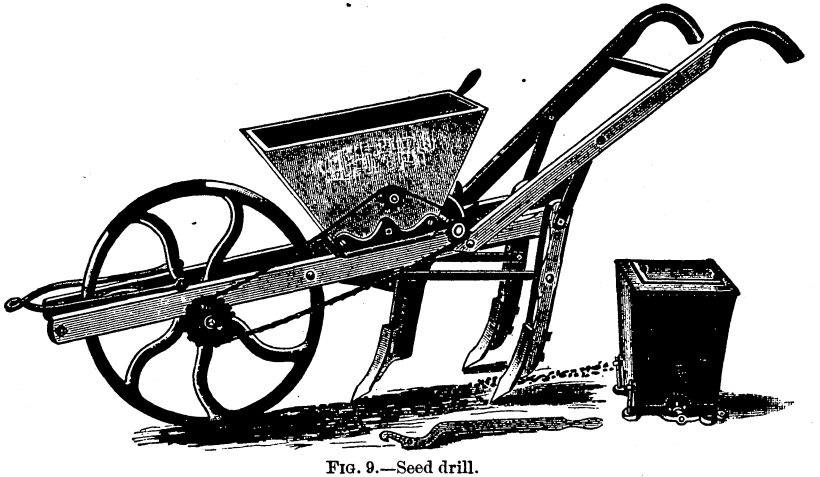

FIG. 9.—Seed drill.

The land, being exposed through the winter, becomes quite mellowed, and in the spring can be prepared for planting by a simple treatment of the surface. This is done after plowing by a thorough surface

cultivation until the surface of the soil is reduced to perfect tilth. The large cultivator shown in fig. 7 can be conveniently used for this purpose, followed when necessary by a harrow and roller. It is desirable, however, that each portion of the field to be planted should be thoroughly prepared immediately before the planting takes place. For instance, if the planting is to be made on a given day, the soil should be thoroughly prepared on the previous day. Thus all weeds and grasses which have started to grow are killed, and the beets have an even chance with the weeds for growth. If, on the other hand, the soil be prepared a week or even a few days before planting, the weeds and grasses get a good start, and it is difficult to free the beets therefrom.

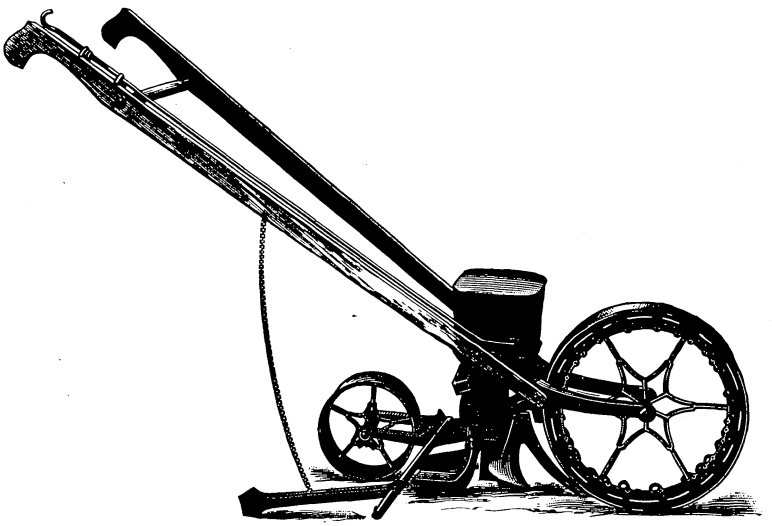

FIG. 10.—Hand seed drill.

PLANTING.

The beets may be planted either by hand or by drill. Hand planting may be practiced when a very small plat is to be put in beets, but where a field embracing several acres is to be planted it is not convenient. In such cases planting by drill is best. Almost any garden drill can be adapted to use with beet seed. Special drills for sugar-beet seed are made by many manufacturers of agricultural implements. One is shown in fig. 8. The form of drill represented in fig. 9 may also be used. In planting by drill it is necessary to use from 15 to 20 pounds of seed per acre; in planting by hand from 10 to 15 pounds will be found sufficient.

Another very convenient hand drill, which is especially fitted with a beet-seed dropping apparatus, is shown in fig. 10. This machine marks and excavates the row, drops the seed at any required distance, and covers it.

The beets should be covered to the depth of from one-half to 1½ inches, according to the state of the soil. If the soil be moist and in excellent condition, the beet seed should not be covered more than half an inch. If, on the other hand, the soil be very dry and early rains are not probable, the seed should be covered to the depth of 1½ inches.

In large cultures it is often important to be able to plant more than one row of beets at a time. For this purpose the planter shown in the accompanying figure (11) is convenient. The machine is adapted to planting four rows at a time. The runners can be adjusted at any distance from 16 to 20 inches apart and the quantity of seed planted can be varied from 15 to 25 pounds to the acre.

In planting by hand or by drills an effort should be made to distribute the seeds singly and at equal distances apart.

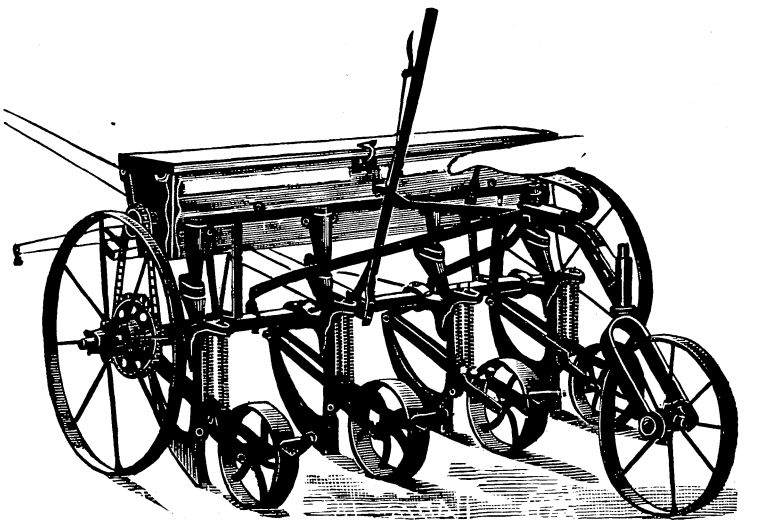

FIG. 11.—Seeder for four rows.

TIME OF PLANTING.

Beets should be planted as early in the spring as possible. Experience has shown that the early planted beets almost uniformly produce a larger yield and with a higher content of sugar than the late planted. No exact date can be fixed which would be suitable to all localities. In most of the localities in the beet area of the United States it will not be found practicable to plant earlier than the first week in May. In exceptional seasons a part of the sowing may be accomplished in April.

On the Pacific Coast, especially in central and southern California, the sowing can take place at a much earlier date. At Chino planting has been practiced in December with favorable results. In 1895 one acre of beets planted in the autumn yielded at the rate of 12½ tons per acre, with an average sugar content of 15.2 per cent and a purity

of 81.5. In the same field 8 acres planted in the spring yielded only 5 tons per acre, with an average sugar content of 14.7 and a purity of 80.5. It was observed, however, that the autumn-planted beets had a higher content of marc than those planted in the spring. Under date of January 4, 1897, the agricultural manager of the Chino Beet Sugar Factory wrote that he had planted 5 acres of beets on the 21st of December and that they were then well out of the ground.

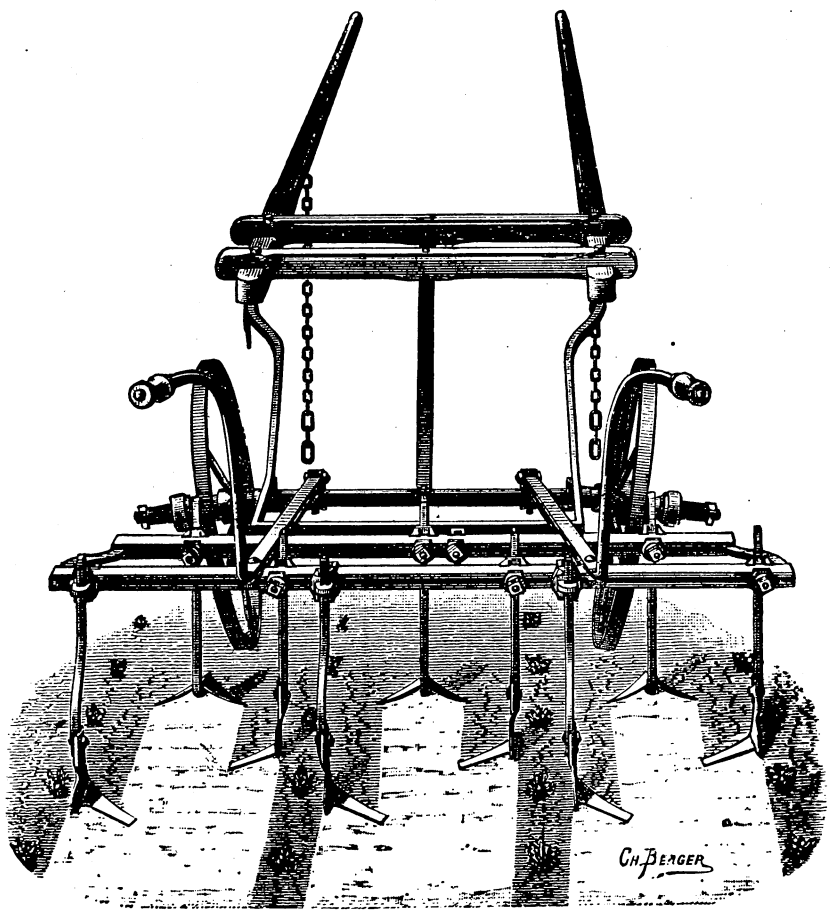

FIG. 12.—Horse hoe.

He further stated it to be the intention of the company to continue the experiments of autumnal and winter planting on a more extensive scale, and to plant from 50 to 100 acres in the autumn of 1897 for the harvest of 1898. In this connection it must be remembered that the climatic conditions of the Chino Valley are almost unique for beet-sugar production, and the experience there obtained would not be applicable to beet sugar regions in general.

CULTIVATION.

As soon as the beets are large enough to mark the rows, cultivation with the horse or hand hoe may be commenced. Cultivation must not

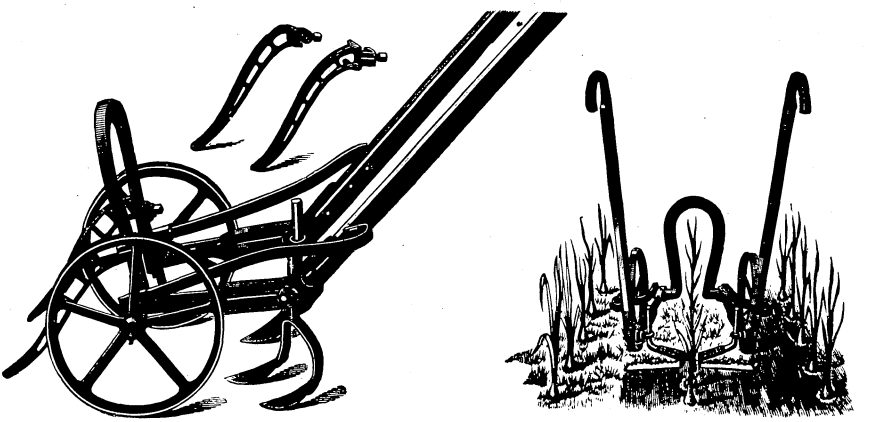

FIG. 13.—Hand hoes.

be postponed, except for unfit condition of the soil, if the grass and weeds appear above the ground at the same time with the beets.

When large fields are cultivated, the horse hoe, a model of which is

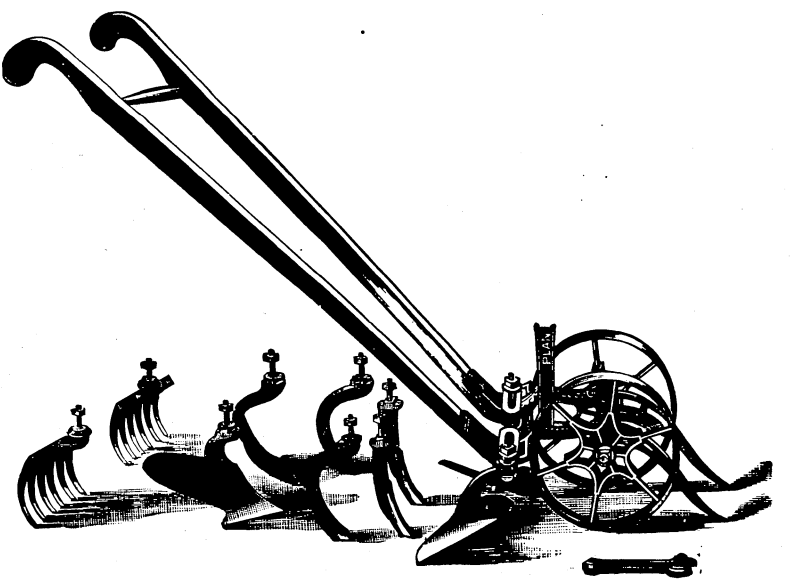

FIG. 14.—Cultivator for beets.

shown in fig. 12, may be used. For smaller fields a similar apparatus drawn by hand may be employed. Convenient instruments of this kind are shown in figs. 13 and 14. This plow frees the spaces between

the rows of beets from weeds and the guard prevents the growing beets rom being covered by the loose soil.

When the beets show four leaves the process of thinning should take place. If the rows be 18 inches apart a vigorous plant should be left

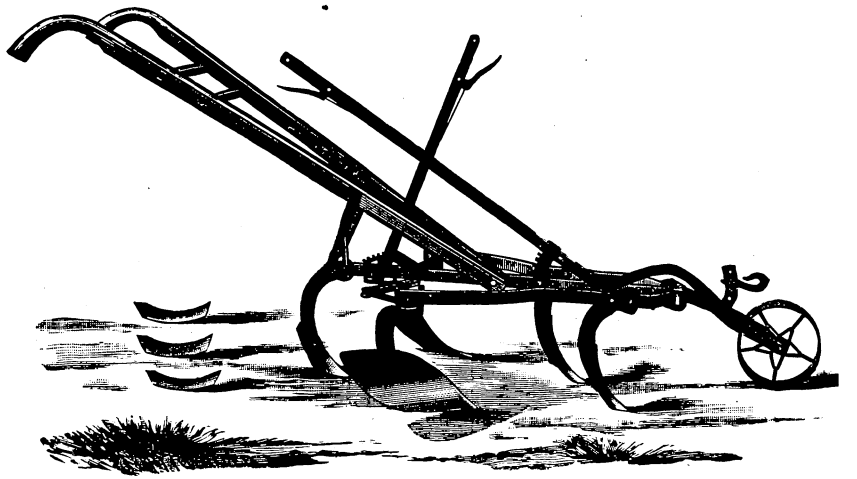

FIG. 15.—Deep cultivator.

every 8 or 10 inches. Careful selection should be made and all the puny plants destroyed. It is better to save the vigorous plants even if regular intervals are not preserved, but no space should be left greater

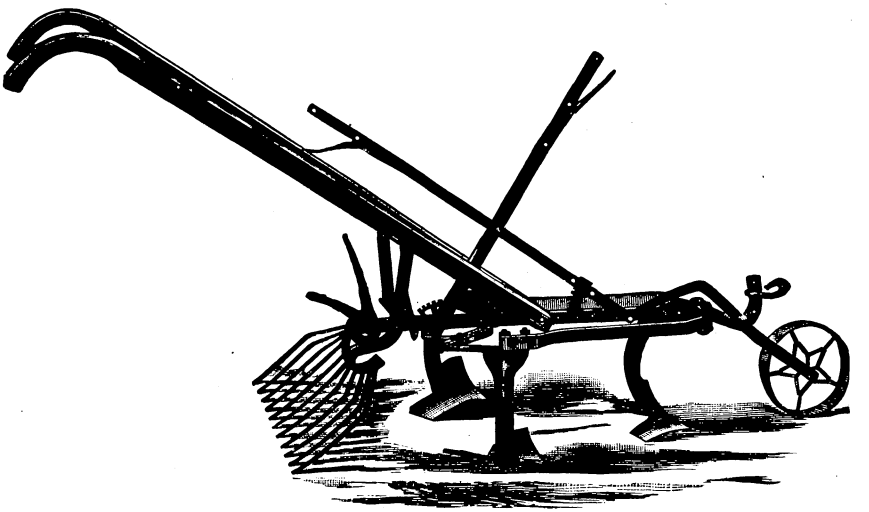

FIG. 16.—Plow cultivator with harrow.

than from 12 to 15 inches in extent. Much of the thinning work can be done with a narrow hoe, but where the plants are very close together, at the place where the preserved plant is to grow the work must be done by hand. It is well to give a thorough hand hoeing at the time of

thinning, and the subsequent cultivation, in most seasons, may be carried on with horse power.

When the beets are more advanced a few deeper cultivations may be desirable, and for these any good narrow cultivator may be used for

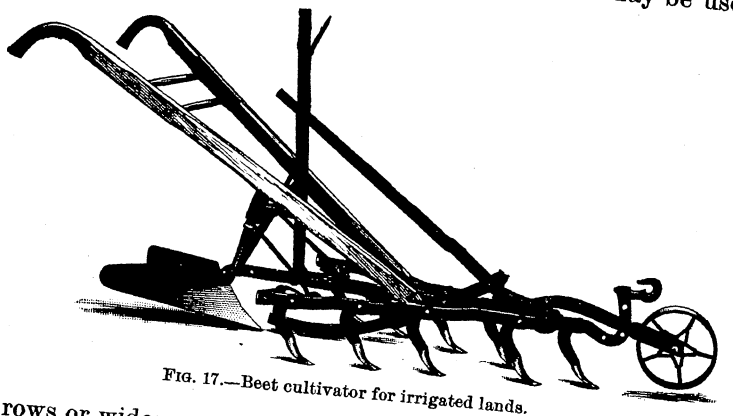

FIG. 17.—Beet cultivator for irrigated lands.

single rows or wider ones for double rows. The instruments shown in figs. 15 and 16 will be found suitable to this kind of work.*

The cultivation in all cases should be conducted for the double pur-

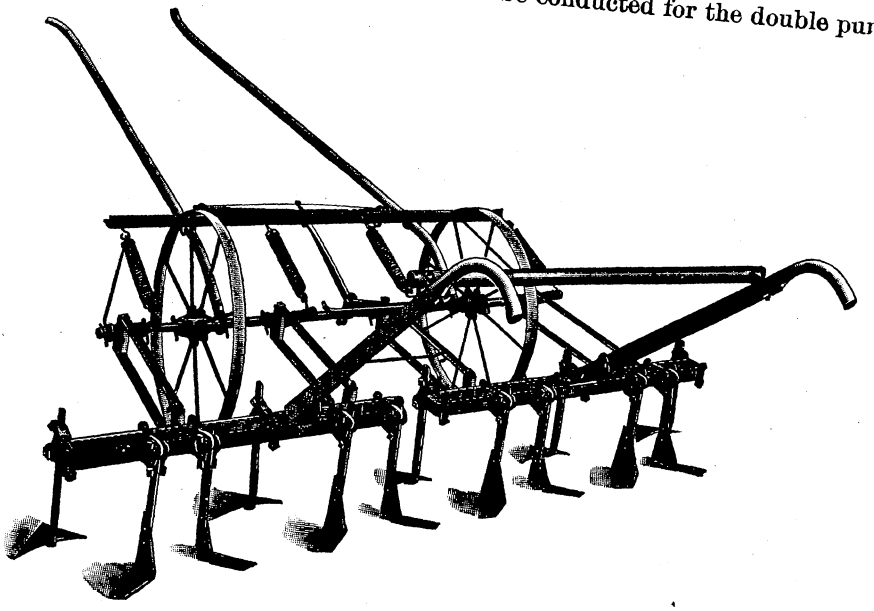

FIG. 18.—Cultivator for four rows.

pose of keeping the beets entirely free of weeds and for preserving

* Many of the illustrations of cultivators are from electrotypes kindly furnished by S. L. Allen & Co., of Philadelphia, the Moline Plow Co., and the Deere-Mansur Co., of Moline, Ill.

the proper tilth of the surface of the soil. It may be said that at least once a week during the period of growing, lasting from six to eight weeks, the beet field should be cultivated. If the season be very dry, more frequent cultivation will be found useful. The final cultivation should leave the soil practically level. During cultivation care should be taken not to injure either the leaves or the root of the beet, and when the foliage of the growing crop begins to cover well the surface of the soil cultivation may be suspended.

In growing beets with irrigation a cultivator which will prepare the furrow for conducting the water over the field is important. Such a machine is shown in fig. 17. In this instrument the plow shown in the rear of the cultivator teeth forms the required furrow and can be set at any required depth. In ordinary cultivation, the brush harrow shown in fig. 16 can be inserted in place of the plow.

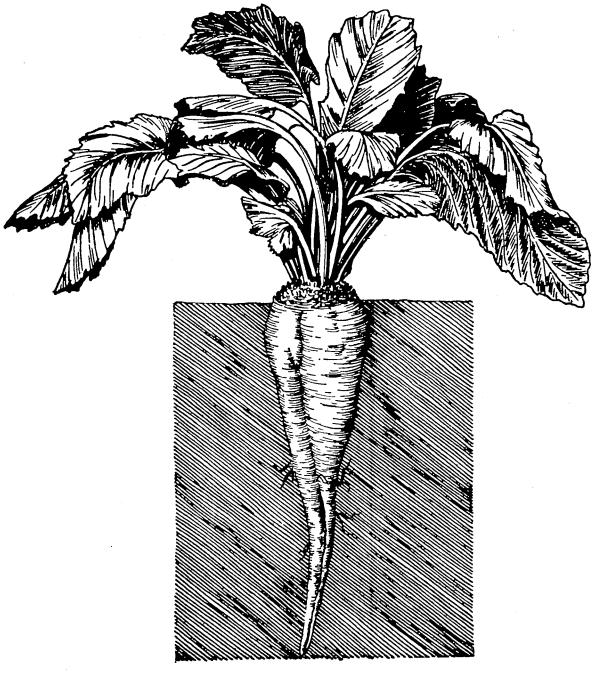

FIG. 19.—Correct position of a mature beet in the soil.

In the cultivation of large areas, an implement adapted to four rows of beets is desirable. Such an implement, however, can not be advantageously used, except in those cases where the beets have been sown with an implement of similar capacity. The cultivator shown in fig. 18 is suitable for use on fields which have been planted with the seeder shown in fig. 11. The gangs of plows in this instrument are easily handled by a spring lift, and by reason of a peculiarity of construction run steadily and adapt themselves exactly to the rows, so that the operator needs only to watch a single row. Different kinds of implements for cultivation can be easily attached so that the instrument can be used as a plow, a cultivator, or a harrow.

POSITION OF THE BEET IN THE SOIL.

It is important not only that a sugar beet should be of a proper size and shape, but also that it be grown in such a manner as to secure the

protection of the soil for all of its parts except the neck and foliage. The proper position for a beet to occupy in the soil at the end of growth is shown in fig. 19. This position can only be secured for the beet by growing it in a soil sufficiently pervious to permit of the penetration of the taproot to a great depth. It is for this reason that subsoiling in the preparation of a field for the growth of sugar beets is of such great importance. If the beet, in its growth, should meet a practically impervious subsoil at the depth of 8 or 10 inches, the taproot will be deflected from its natural course, lateral roots will be developed, the beet will become disfigured and distorted in shape, and the upper portion of it will be pushed out of the ground. Experience has shown that the content of sugar in those portions of a beet which are pushed above the soil is very greatly diminished.

COST OF GROWING BEETS.

The cost of growing an acre of beets depends on so many varying factors as to render it impossible to give an estimate which is reliable for every locality. The differences in rent of land, cost of labor, methods of culture, etc., require that any estimate which may be given should be revised for almost every series of conditions. The following estimate of maximum cost per acre is based on the supposition that land is worth $75 per acre, labor $1 per day, the yield 15 tons per acre, and that the distance to the factory is not greater than 3 miles:

Rent of land	$5.00
Plowing, subsoiling, and preparing for planting	5.00
Fertilizers	10.00
Cost of seed	2.25
Planting	1.75
Hoeing and thinning	6.00
Cultivating with horse hoe five times	5.00
Harvesting	5.00
Topping	12.00
Delivering to factory	7.50
Total	59.50
Value of 15 tons, at $4.50	67.50

In the above estimate has been included the cost of the best culture and a reasonable application of fertilizers. It is probable that the actual cost to our farmers for the first few years of the beet industry will not exceed $45 or $50 per acre and in many instances will fall below these figures. The price paid for the beets is dependent on many local considerations, but chiefly on the selling price of sugar and the richness of the beet.

It is reasonably certain, accidents of season aside, that a net profit of from $8 to $15 per acre may be expected from the proper culture of the sugar beet in localities near a factory when all the conditions of the best methods of culture are fulfilled.

In contrast with the above estimate, the actual figures submitted by Mr. J. Thomssen, of Hall County, Nebr., in a letter published in the

Prairie Farmer, on the 3d of January, 1891, are given. The cost is given for a field of 5 acres, and the items are as follows:

Fall plowing, at $1 per acre	$5.00
Plowing in spring, at $1.25	6.25
Rolling twice, once before and once after planting	1.50
Planting by hand, at 75 cents per acre	3.75
Cultivating with hoe, at 75 cents	3.75
Thinning, at $10	50.00
Hoeing by hand three times and weeding necessary at time of hoeing	90.00
Cultivating by horse twice, at 75 cents	7.50
Running over with hoe to clear from remaining weeds	3.75
Total	171.50

Dividing this by 5 gives a total of $34.30 per acre.

As will be seen from the above, Mr. Thomssen makes no allowance for the rent of the land, used no fertilizers, and gives no estimate of the price of seed and of the expense of harvesting and hauling to the factory. But his field was hoed by hand three times, which with the proper implements is more than is necessary, one good hand hoeing being as a rule sufficient.

The average cost per acre of raising sugar beets in France is given by a French statistician as follows:

Farmyard manure	$28.00
Commercial fertilizers	12.00
Spreading manure	.60
Spreading fertilizers	.25
First plowing	1.60
Harrowing and rolling after plow	.64
Plowing and subsoiling	4.60
Two scarifyings	2.00
Two harrowings	.64
Two rollings	.64
Cost of seed	3.00
Sowing of seed	.80
Harrowing and rolling again	.64
Three times hoeing with horse	2.40
Hoeing by hand	4.80
Harvesting by machine	1.60
Lifting and topping	4.00
Carting to factory	2.40
Total	70.61

To the figures stated are still to be added the rent of land and taxes, $9.40, making a total of $80.01.

The charge for harvesting is very low, from the fact that the topping of the beets is performed by women and children, whose average wages probably do not exceed 15 cents a day, much less than the estimates call for in this country, while the charge for fertilizers is much greater than would be necessary in this country for some years to come. The average yield per acre obtained by M. Du Fay, the author of the above estimate, was 25 tons, showing the value of intensive farming.

Mr. J. B. Henderson, of Alameda, Cal., reports the cost of growing and harvesting 10 acres of beets at $614.83, or $61.48 per acre. His farm is 1 mile from the factory. Mr. A. F. Richardson, of the same place, residing 2 miles from the factory, reports the cost of 11 acres at $535.04, or $48.64 per acre.

It is not wise to underestimate the actual cost of growing the beets, for this will lead the farmer to expect large profits which often in practice give way to actual deficits.

HARVESTING.

The time for harvesting varies in different localities. In southern California the beets planted in February are ready for harvesting in August. In general it may be said that beets planted the first week

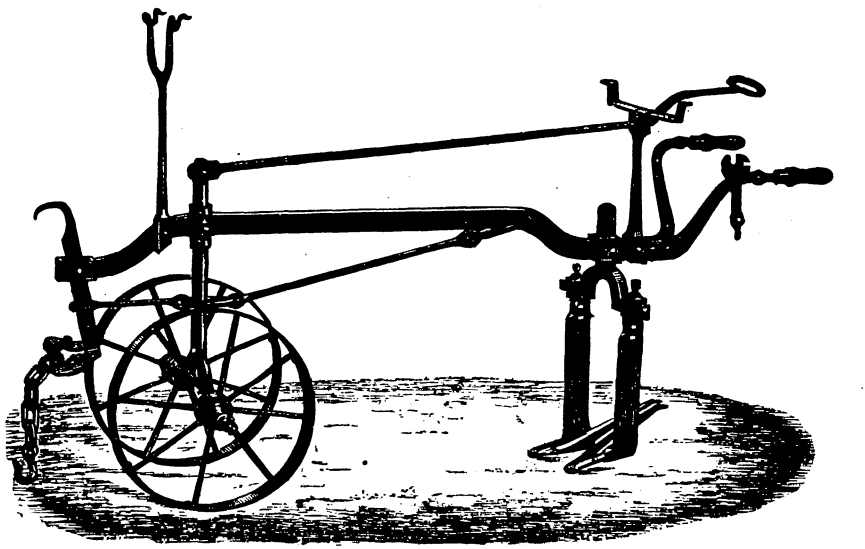

FIG. 20.—Beet harvester for one row.

in May will be ready for harvesting about the first of October. Harvesting should be postponed to as late a date as possible, provided the beets are in no danger of a second growth and are not exposed to a freezing temperature. The leaves of the ripened beet change from a rich to a yellowish green, become drooping and applied closely to the earth, and many of them die. The harvesting is easily accomplished by first loosening the beets in the soil and then removing them by hand. For loosening the beets, the apparatus shown in fig. 20 may be employed. It can be used to advantage only when the rows are perfectly straight and the beets of a reasonably uniform size. The teeth of the apparatus are sunk deep enough into the earth to catch the beet below its middle part. In moving forward the plow catches the beets between its two prongs, which approach more nearly together in the rear, and

on account of the angle at which the teeth are fixed the beets are lifted and the tap roots broken. After the passage of the harvester the beets are easily lifted out of the ground by means of their leaves.

The next operation consists in removing the neck. This is done by a large knife and the top of the beet, called technically its neck, is cut off so as to remove, with the top, that portion of the beet to which the stems of the leaves have been attached.

The object of removing this portion of the beet is to prevent the mineral salts, which have accumulated in large quantities therein, from entering the factory. These mineral salts exercise a very deleterious influence on the crystallization of the sugar, and, therefore, should be removed. They are well fitted for feed or for fertilizing purposes and are of more value when left upon the soil than when removed to the factory. The neck is also much less rich in sugar than the other parts of the root.

The removal of the tops of the beets is a tedious process which, in Europe, is performed by women and children. In this country the process of topping the beets will prove much more expensive than in Europe. It is probable that some mechanical device will be invented by which the beets can be topped, thus saving a large expense. So far as known at the present time, however, this process has not been successfully accomplished by machinery and the topping must still be done by hand.

When the beets are topped they are thrown into piles, and the tops thrown over them as a protection from the sun or frost until they can be delivered to the factory.

The beets are best delivered to the factory in dump carts, which permit of their quick unloading. It is not customary for the farmers to silo their beets except in the simple manner indicated above.

SILOING.

When beets are to be preserved for manufacture during the winter months or for the production of seed, they must be carefully protected against frost. The simplest and the easiest method is to place them in piles and cover them with earth, not too deeply, for if they become too warm in the silo they rapidly lose in sugar content. When first siloed, say, about the 1st of November, they should be covered with only a slight layer of earth; as the cold of winter becomes more intense this covering can be increased. In some localities only a slight covering of straw is necessary to protect the beets, as, for instance, in California. In other localities, such as in the Dakotas, Minnesota, and Wisconsin, it is probable that the beets would have to be covered to the depth of 2 feet, or even more, to protect them from frost.

Siloing is usually done by the factory, as it would be very inconvenient to deliver beets from a distance to a factory in the middle of winter.

In most localities in the beet-sugar region of the United States it is

probable that the harvesting and delivery to the factory could be entirely completed by the middle of November; although in some seasons there would be no danger whatever in leaving the roots in the earth until the 1st or even the 10th of December, while in California there is no danger at all of freezing.

In the construction of large silos due regard must be had for proper ventilation to avoid the danger of heating.

PRODUCTION OF SEED.

The production of seed is one of the most important operations connected with the sugar-beet industry. On the care and skill which are displayed in this process depend the improvement and maintenance of the sugar-producing qualities of the beet. There are many different methods employed for producing seed which will grow the richest sugar beets, but there will be mentioned here only a general outline of the principles which underlie the process. The beets which are to be preserved for seed are called "mothers" and are carefully siloed in the manner already indicated. They are selected at the time of harvesting from specially grown beets or from fields of beets which have shown particularly good qualities on analysis. The size of the roots selected for mothers should be about the average of the best sugar beets, viz, from 20 to 24 ounces. Smaller beets than these might show a higher content of sugar, but it is not wise to produce a race of small beets by selecting the seed from the very smallest and richest beets grown. The weight of the mothers having been decided upon, the beets are next selected for their shape and external appearance. Those regular in shape and smooth in external form are to be preferred. Roots of irregular shape or with more than one tap root should be rejected.

The beets to be preserved for mothers are harvested with unusual care to avoid injury. The neck is not cut away, but the leaves are removed by cutting off the stems without injuring the neck of the beet.

The siloing should be of such a nature as to entirely protect the beets from frost and yet prevent their growth in the silo until the spring. The beets are removed from the silo at an early date in the spring and are immediately subjected to analysis for the final selection. In the early days of the beet industry the beets were selected almost solely on account of their specific gravity. A brine of a given strength was made, and the beets, thoroughly cleaned of dirt, were thrown into this brine. Those which would sink were selected as mothers, while those that would swim were rejected. At the present time the final selection depends upon the actual determination of the density of the juice of the beet which is to be selected as a mother and the estimation of its content of sugar. For this purpose a cylindrical piece of the beet is removed by an appropriate instrument cutting diagonally through the center of the root. This piece may weigh 2 ounces or even more, and its removal does not injure the beet for germinating purposes. The

juice is expressed from this piece, and its specific gravity determined by weighing in it, at a given temperature, a silver button of known weight.

The sugar content of the juice is next determined by means of the polariscope. By means of these two data the qualities of the beet for the production of seed are determined and also the coefficient of purity; that is, the number obtained by dividing the percentage of sugar in the juice by the percentage of solid matters as determined by its specific gravity. In mother beets this number is found somewhere between 80 and 90. The actual method of selection may be illustrated as follows:

The operator determines beforehand his standard, which in most cases will consist of a juice containing from 16 to 18 per cent of sugar with a purity of 85. The beets are analyzed separately, and are at once divided into two great classes, namely, those in which either the content of sugar or the purity falls below the fixed figure, and, second, those in which these two numbers are equal to or exceed the fixed figures. It is sometimes customary to divide these two classes into two portions, viz, those roots in which the numbers are equal to or slightly above the standard, and, second, those which show exceptional richness. It is also customary to number each beet, and the number, which is cut into the skin of the beet, will remain legible even after the seed has ripened. Some of the producers of sugar-beet seed preserve the product of seed from each beet by itself, and do not use it to inaugurate the production of seed for commerce until it has received an additional year's trial.

By this method of careful, scientific culture the sugar beet has been raised to its present high standard of excellence, and is only maintained at this standard by constant supervision, such as has been indicated.

The sugar-beet seed produced by the above method is not sold for planting fields, but is used solely for the production of the seed of commerce in the fourth or sixth year from the parent, as the case may be.

DOMESTIC PRODUCTION OF BEET SEED.

The commercial production of beet seed of pure pedigree and high grade has not been practiced to any extent in this country. The Alameda Sugar Company, and perhaps others, have grown large quantities of beet seed for domestic use, but without any attempt to sustain or increase the sugar content by scientific methods. During the continuance of the experiment station at Schuyler, Nebr., a system for the production of beet seed of exceptionally high grade was inaugurated, embodying all the best features of the methods practiced in Europe. In the spring of 1893, 6,370 beets, which had been carefully selected on account of their physical characteristics and preserved in a silo over winter, were subjected to an analysis by removing a cylindrical core from each one and subjecting the expressed juice therefrom to a chem-

ical examination. Allowing for the deterioration in sugar content which the beets had suffered during storage, the beets were classified by the analysis as follows:

Variety.	No. I grade (sucrose 18 per cent upward).	No. II grade (sucrose 15 to 18 per cent).	No. III grade (sucrose 12 to 15 per cent).
	Beets.	*Beets.*	*Beets.*
Original Kleinwanzlebener	36	465	448
Dippe's Kleinwanzlebener	6	483	1,176
Vilmorin's Improved	8	600	784
Lemaire	.....	.....	476
Desprez	.....	.....	168
Elite Kleinwanzlebener	7	210	224
	57	1,758	3,276

The following statement gives the proportion of the beets analyzed which was eligible for propagation uses:

Number of beets of all grades accepted for seed production	5,091
Number of beets of all grades rejected for seed production	1,179
Total	6,270

By reason of the abolition of the experiment station the beet seed produced was sold to the highest bidder for a sum which would have brought for an acre under cultivation $172.60.

PRODUCTION OF COMMERCIAL BEETS FROM A SINGLE HIGH-GRADE BEET.

In the case of any given variety let it be assumed that a beet is found of good size and typical form, and exceptionally rich in its sugar content and the purity of its juice. The production of beets on a commercial scale from this single individual is accomplished as follows: The beet is preserved over winter and planted in the spring for the purpose of producing seeds. The seeds thus obtained are carefully freed from all imperfect and defective individuals, and planted the second year for the production of beets. Several hundred beets will likely be produced from this sowing. All of these beets which are of proper size and good form are preserved during the winter. In the third spring they are all carefully analyzed and those which reach or exceed a given standard are planted for the production of seed. It is probable that during this third season several thousand beets will be produced. All those which are of typical size and shape are preserved over the winter and the fourth spring are planted without analysis, and the seed which they yield will be of sufficient quantity to be used in the fifth year for the production of sugar beets for the factory. It is seen by the above statement that at least five years are required for the production of seed for commercial purposes from any high-grade individual beet which may be selected for the purpose.

COMPARATIVE VALUE OF DOMESTIC AND FOREIGN GROWN SEED.

In the experiments conducted at the station at Schuyler during the season of 1893 a comparison of the beets grown from domestic and imported seeds was made. The plants from the native-grown seed seemed to have a higher vitality and to be better suited to the climatic conditions of the locality than those grown from imported seeds. They showed during the growing season a more abundant foliage and a better development of roots. This higher vitality and quality of the beets grown from domestic seed illustrate in a forcible degree the advisability of the production of our beet seed at home. Even granting that seeds produced in foreign countries have the same high qualities, it must be admitted that their vitality is in danger of being very much diminished during shipment to this country. The moist air of the holds of the ships in which they are transported often produces moldiness and incipient germination, which tend to greatly diminish their value. Not only did the beets produced from the home-grown seed have a higher percentage of sugar, but they also afforded a higher yield per acre, as determined in the experiments at Schuyler. The mean tonnage per acre from the home-grown seed was 21.1 and from the imported seed 17.9. The mean pounds of sugar produced per acre from the home-grown seed was 5,891 and from the imported seed 5,185. This shows an increase of about 12 per cent in the actual quantity of sugar per acre when domestic seed was used. These data should be carefully studied by all those who are interested in the production of beet sugar in this country. Perhaps the time has not yet come for the inception of such a work, but it is evident that it will not be long before there will be a demand for the establishment in this country of a plantation or plantations devoted exclusively to the production of beet seeds on the most approved scientific principles.

The quantity of seed required to plant an acre is about 15 pounds. The approximate number of acres planted to beets in this country during the season of 1897 was 45,236, requiring 678,540 pounds of seed. It is evident that there is already an opportunity for the active operation of a large plantation devoted exclusively to the production of beet seeds for domestic use.

Another point to be considered is that by the importation of foreign seeds there is danger of introducing those fungoid and microbian diseases of beets which have produced such ravages in Europe.

MANUFACTURE OF SUGAR.

The process of making sugar from the sugar beet interests the agriculturist only from secondary considerations, and will be treated in the briefest possible manner to give an intelligent idea of its methods.

The beets are first conveyed to washing tanks provided with suitable apparatus for keeping them in motion and transferring them toward

the end from which the fresh water enters, in order that the whole of the adhering soil, together with any sand and pebbles, may be completely removed. By a suitable elevator the beets are next taken to a point above the center of the diffusion battery, shown in fig. 21, whence

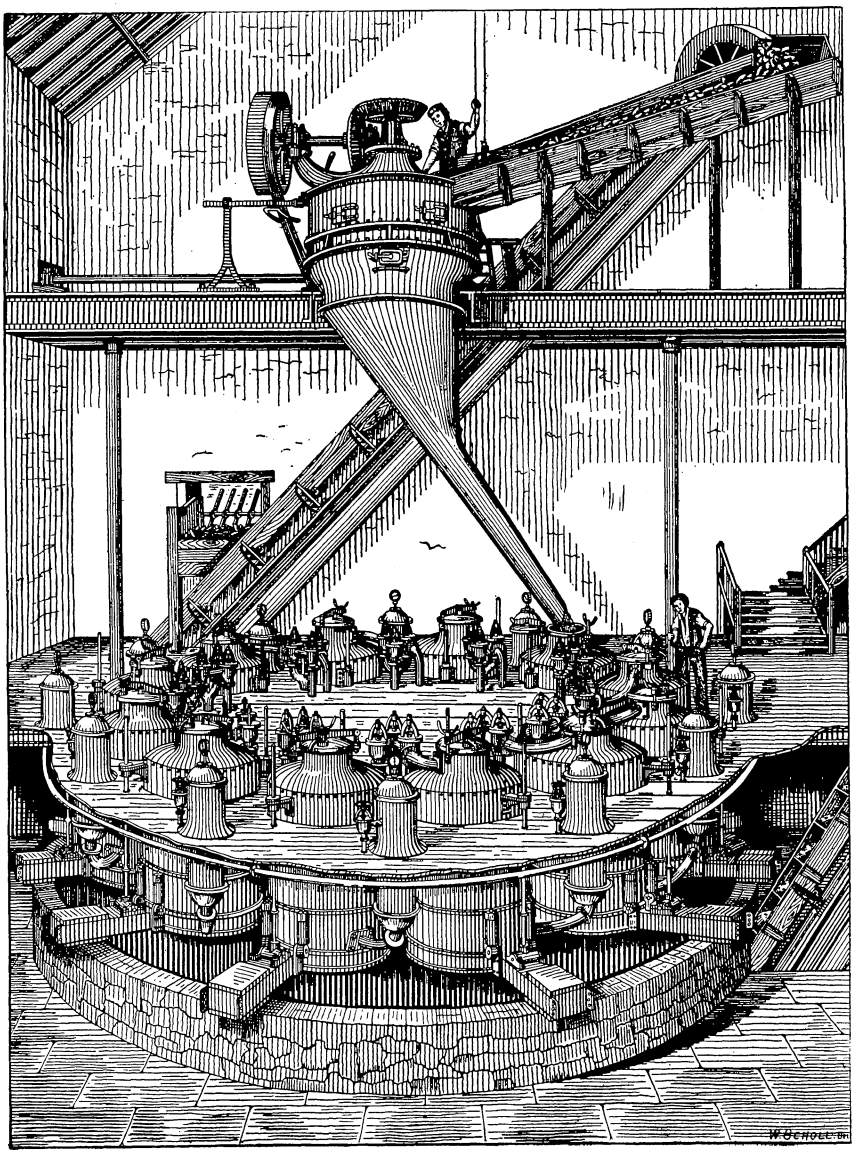

FIG. 21.—Diffusion battery.

they are dropped into a slicing apparatus, by which they are cut into pieces of greater or less length and of small thickness, and of such a shape that when placed in the cells of the battery they will not lie so closely together as to prevent the circulation of the diffusion liquors,

When the cell is full of the sliced beets it is closed and the hot juices from the cell last filled are admitted and allowed to remain in contact with the cuttings for a few minutes. From 10 to 12 cells are thus kept in use. While one is filling another is emptying. The fresh hot water is always admitted to the cell next to be emptied and passes in succession through all the cells under pressure, until it reaches the one last filled. From this cell a quantity of juice is drawn off each time and sent to the clarifiers for purification.

The extracted cuttings are carried through a press by which a portion of the water is removed, and they are then in suitable condition for use as cattle food. The diffusion juices obtained as above described are carried to carbonatation or saturation tanks, where they are treated

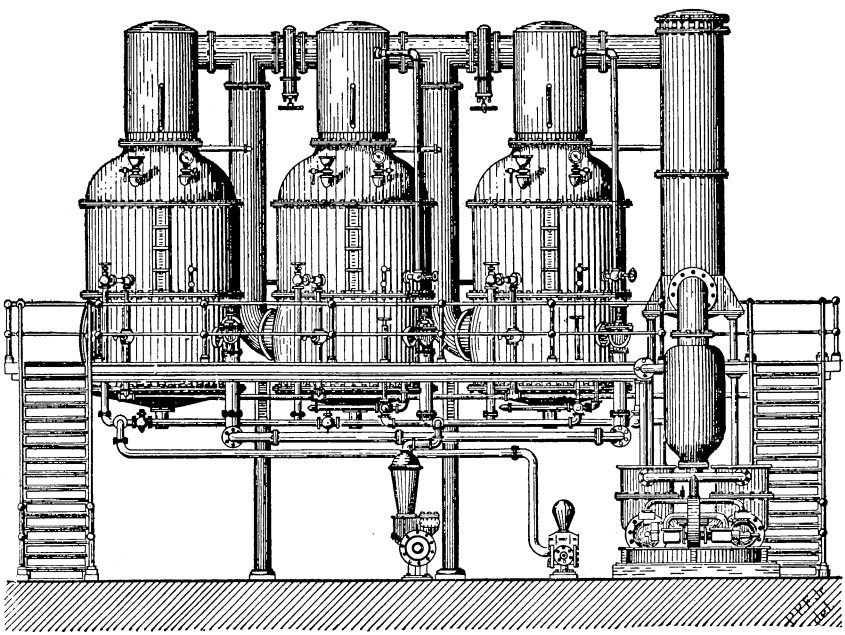

FIG. 22.—Multiple-effect evaporating apparatus.

with from 2 to 3 per cent of their weight of lime and afterwards with carbonic acid until nearly all of the lime is precipitated. The slightly alkaline juices are next passed through filter presses, by which the precipitated lime and other solid matters are removed. The juices pass next to a second set of carbonatation tanks, in which they undergo a treatment in each particular similar to the one just mentioned, except that the quantity of lime added to the second saturation is small as compared with that of the first. The refiltered juices from the second saturation are carried to the multiple-effect vacuum pan and reduced to the condition of sirup.

The multiple-effect evaporating apparatus (fig. 22) consists of a series of pans connected en suite in such a manner as to secure a progressively

higher vacuum in each one. The thin juices enter the first pan, where they are evaporated at a vacuum represented by a column of 8 or 10 inches of mercury. The steam with which this evaporation is effected is usually the waste coming from the engines and pumps of the factory. The vapors generated in the first pan enter the heating pipes of the second one, and are thus utilized in evaporating the somewhat concentrated sirup which is drawn off from the first pan into the second one, where the vacuum is higher, being represented by a column of mercury of from 16 to 18 inches in height. The vapors which are produced in the second pan are in like manner conveyed to the heating pipes of a third apparatus, where the still more concentrated sirups from the second pan are conducted and evaporated at a still higher vacuum of from 22 to 26 inches of mercury. Sometimes a fourth pan is employed, but the arrangement is fully illustrated by the above example. It is easy to see by the arrangement above noted that the evaporation of the thin diffusion juices to a heavy sirup is accomplished with the greatest economy, steam being admitted only into the first pan, and the rest of the operation being automatic, aided only by the pumps producing the vacuum. The sirups thus produced are converted into sugar in the following manner:

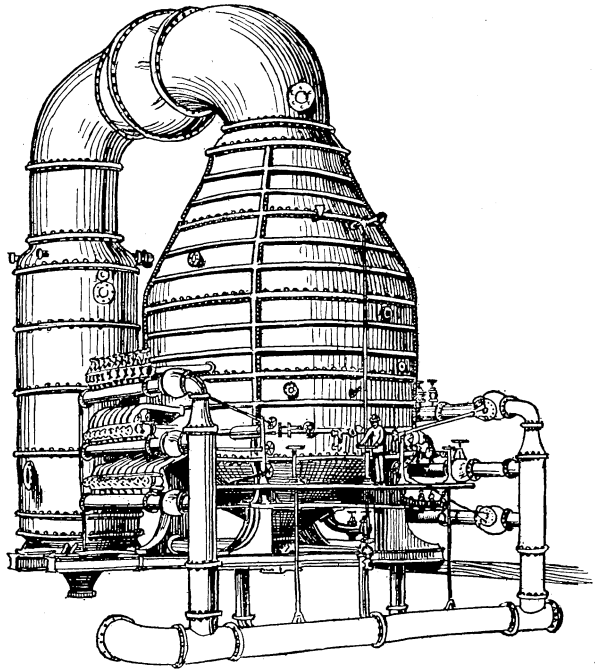

FIG. 23.—Vacuum strike pan.

A portion of the sirups is placed in an evaporating apparatus called the strike pan. This apparatus is very large, usually of a pear shape, with somewhat straight sides, and provided with a series of coils, one above the other, to which the steam can be admitted at will. The admission of steam is always so regulated that it is not allowed to enter any of the coils above the surface of the liquid in the pan. The portion of sirup first introduced is evaporated until it reaches a point of consistency which will permit of the formation of crystals. In this condition, if a portion of fresh sirup be quickly introduced the whole mass in the pan

becomes charged with exceedingly fine crystals of sugar. By careful manipulation and the introduction of new quantities of sirup from time to time these crystals are made to grow. As the pan becomes full successive coils of the steam pipes are brought into use, so that the boiling surface of the pan is gradually increased in proportion to the volume of its contents. In the course of a few hours the skilled sugar boiler will find that the pan is full and that the crystals have grown to the proper size. The mass in the vacuum pan at this stage is extremely heavy, consisting of a dense mass of sugar crystals mixed with a quantity of molasses greater or less in amount, as the juices from which the sugar is made are more or less pure. The illustration of the vacuum pan (fig. 23)

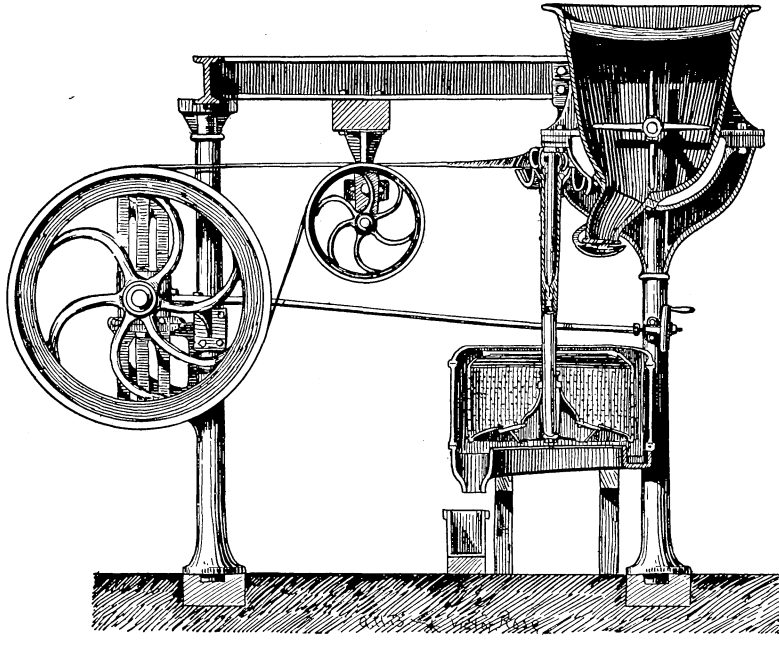

FIG. 24.—Centrifugal apparatus.

is from a photograph of a large pan, 17 feet in diameter and 42 feet high, intended for refinery use. This pan turns out 1,000 barrels of sugar at each strike, and the time required for boiling is about three hours. It is constructed on exactly the same principles as the smaller pan employed in beet-sugar factories. In boiling sugar in a vacuum pan, if the highest possible yield is desired and no objection arises to the formation of soft crystals, a very high vacuum, equivalent to 29 inches of mercury at the sea level, is employed. At this vacuum the sirups boil at a temperature of from 112° to 120° F. If harder crystals, giving a somewhat less yield, are desired, as in the case of making granulated sugars, a lower vacuum, namely, from 24 to 26 inches, is employed.

The sirups are reduced in the vacuum strike pan into sugar called

massecuite, which contains from 6 to 10 per cent of water. This is then carried directly to the centrifugals, where the molasses is separated.

The construction of the centrifugal apparatus is shown in fig. 24. A lining of wire gauze permits the molasses to pass outward under the impulse of the centrifugal motion, while it retains all the crystals of sugar except those fine enough to be entrained with the escaping liquid. The uncrystallized sirups together with the water are separated from the sugar by the centrifugals, and form the molasses. The molasses is either reboiled and a second crop of crystals obtained, or it is treated in various ways for separating the sugar which it still contains. One of these methods which has come into general use is known as the Steffen process. In this method the molasses is diluted with water cooled to a low temperature and treated with fresh-burned, fine-ground lime. The sugar in these conditions forms a chemical compound with the lime which is separated from the other constituents of the molasses by means of a filter press. The lime sucrate thus secured is beaten up to a cream with water, the lime precipitated with carbonic acid, separated by means of a filter press, and the pure sugar juices thus obtained boiled for the separation of the sugar as described above. Another method consists in removing the salts which prevent the crystallization of the sugar by the process of osmosis. A third method consists in the use of strontium or barium hydroxid for the separation instead of lime salts, as in the Steffen process; or, finally, the molasses may be subjected to fermentation and distillation and the sugar therein contained thus converted into alcohol.

The above is the general method used for the manufacture of raw sugar. If refined sugar is to be made, the juices and sirups are passed over bone black to decolorize them and the crystals are washed in the centrifugal in order to make them perfectly white. The small, hard, colorless crystals thus obtained when dried in a revolving drum form the granulated sugars of commerce. Another method consists in treating the juices with sulphurous acid and purifying the crystals by washing them with sirup of varying degrees of consistency until all the molasses adhering thereto is washed away.

HOME MANUFACTURE OF SUGAR.

The question is often asked if beet sugar can not be made in a small way so that farmers could club together, put up a cheap apparatus, and produce their own sugar. On account of the elaborateness of the process and the costly nature of the machinery which is necessary to produce beet sugar even in a small way, it is not believed that it could be profitably made in the way indicated. A small factory could not possibly compete with a large one, and hence there is no encouragement to be offered in the way of producing homemade beet sugar. The Department has no knowledge of any successful beet-sugar factory of this kind. There is no country producing any notable quantity of beet

sugar in which home apparatus costing only a few thousand dollars have any appreciable influence on the output of sugar. Russia has been cited as an exception to this rule. The output of beet sugar in Russia annually is about 750,000 tons. The total number of factories in operation is about 300. The average annual output of each factory in round numbers is 5,000,000 pounds, representing an average consumption of 25,000 tons of beets. From these figures it is seen that the average size of the Russian beet-sugar factory is not greatly different from that of other European countries.

WASTE PRODUCTS.

The waste products of the factory consist of the pulps and molasses. The molasses is used for various purposes, either for making sugar, as described above, for fertilizing purposes, for the manufacture of alcohol, or sometimes for cattle food. The pulps make a valuable cattle food. They may be fed in the fresh state or preserved in silos. Lately extensive experiments have been made in drying the pulps and preserving them in the dried state, and these experiments have been fairly successful. It is stated that the value of the pulps for feeding purposes is from one-fourth to one-fifth of the value of the beets.

COST OF MANUFACTURE.

The cost of manufacture depends on as many factors as that of beet growing. Chief among these are transportation, fuel, weather, and labor. Perhaps the most important of these factors is the price of fuel. In some localities coal can be had for $1.25 per ton; in others the cost may reach as high as $10 per ton.

The manufacture of beet sugar is conducted without governmental supervision in this country, and any exact account of its cost is inaccessible. To show what it may be, with large experience and the highest skill and management, the mean cost of manufacture in 113 German factories is given:

Mean capital invested in each factory		$193,400.00
Total receipts for sugar, molasses, and pulps per ton of beets		11.10
Mean cost of beets per ton of 2,204.62 pounds	$4.90	
Salaries per ton of beets	.26	
Labor per ton of beets	.73	
Interest on investment per ton of beets	.36	
Coal per ton of beets	.63	
Miscellaneous expenses per ton of beets	.96	
Total expense of manufacture per ton		7.84
Profit per ton of beets		3.26

The mean net profit for each factory was $34,240. The price paid for beets, however, is in most cases fictitious, the beet growers owning the

factory and preferring to share in the general profits rather than to charge a high price for the beets. First-class beets rarely sell for less than $5 per ton. The Western Beet Sugar Company, of Watsonville, Cal., stated that in its first campaign, 1888–89, the cost of manufacture amounted to $80.80 per ton of sugar. At the present time it appears that with the best machinery and most economical processes beet sugar can be made in this country at a cost of from 3 to 4 cents per pound when the price of rich beets does not exceed $5 a ton.

COST OF FACTORY.

The cost of building a first-class beet-sugar factory is much greater than is commonly supposed. From the most reliable data at hand it may be stated that in Europe the cost of erecting a factory with the most modern machinery, of a capacity of at least 300 tons of beets per day, is about $200,000. In this country it is probable that, owing to the increased cost of transportation and the higher price of labor, the cost of a similar factory would be at least $250,000. As has been intimated before, it is not advisable to attempt to manufacture beet sugar with smaller factories or with machinery and appliances which do not represent the latest improvements. It is true that there are many parts of a sugar factory which have not changed much within the last twenty years, but even the multiple-effect apparatus, the strike pans, and the centrifugals, which represent the most stable parts of the machinery, have undergone considerable changes within the time mentioned. Probably one of the greatest dangers which the beet-growing industry in this country will meet is the tendency to begin the erection of a beet-sugar factory with cheap, old, or worn-out apparatus and appliances and without a proper technical study of all the questions involved. The avoidance of this danger is all the more difficult, because there are few engineers in this country who have devoted themselves to the study of this problem, and European experts are not likely to understand and comprehend American methods and measures. Numerous inquiries have been received at this office for directions for making beet sugar with such appliances as a cider mill and sorghum-molasses evaporator might afford. It would not be right to encourage the attempt to manufacture beet sugar in any such way. Nor should the expectation be excited among our farmers that they will be able to make a crude article of sugar which they can dispose of to a central factory for refining purposes. It is best to recognize at the very first the great expense which attends the erection of a sugar factory and the necessity for its meeting every modern requirement. Beet growing and beet-sugar manufacture are two distinct industries, but with common aims and interests.

It is seen from the foregoing paragraph that the farmer can have no reasonable hope of successfully establishing a home beet-sugar factory. It is not just, however, that he should be deprived of any cooperation in the process of manufacture or a reasonable share of the profits arising therefrom. The methods which have been practiced in Europe for securing these results are probably those which will eventually come into use in this country. The cooperative sugar factory, in which the farmers growing the beets hold a part or the majority of the stock, realizes the desired end. The growers of beets holding shares in the factory have a greater interest in its prosperity, try to grow better crops, and to secure in every way a higher yield. The cooperative factory renders impossible those disagreements between capital and agriculture which do so much to retard the progress of the industry and to embitter the feeling of the farmer against the factory. To show the extent of the participation of shareholders in factories in the growing of beets in Germany, it may be stated that of the 11,672,816 metric tons of beets delivered to the German factories in 1895–96, 2,689,004 tons were grown by shareholders. Inasmuch as the farmers in a beet-sugar community are uniformly prosperous, they are able to subscribe for shares in a factory, and by a community of interests practically control its operations. The industry of growing beets is not yet sufficiently advanced in the United States to render possible any definite outline of the best plan of securing cooperation between the farmer and the capitalist. At the outset, it would probably be impossible to secure among the farmers alone a sufficient amount of capital to properly equip a factory. Even could this be done, the additional difficulty would be encountered of a lack of experience among the shareholders, leading to poor judgment in regard to the methods of conducting the manufacturing operations. As long as the proprietors of the factory and the farmers growing the beets are satisfied with the contracts which they make, there is no urgent necessity of the establishment of cooperative enterprises. When the number of beet-sugar factories in this country, however, begins to reach the hundreds, favorable opportunities of cooperative establishments will be presented.

STATISTICAL.

Unit of value.

In the data giving the production and consumption of sugar the unit of value commonly employed is the ton. By reason of the fact that the ton in this country expresses a unit of varying magnitude a considerable degree of confusion is often introduced into statistical tables. In the following data, when not otherwise expressed, the term ton is used as the representative of 2,240 pounds. The short ton, namely, 2,000 pounds, is a more convenient unit of expression, but is not used

by Willett & Gray, the publishers of sugar statistical data in this country. The metric ton, which is used on the continent of Europe, is a weight of 1,000 kilograms, equivalent to 2,204.62 pounds.

In the tables which follow some slight differences will be noted in data relating to the same subject. These differences arise from the impossibility of securing exact statements relating to statistical data. Not having at hand the means of revising the statistical tables, it has been thought best to give the figures of the best authorities without attempting to harmonize them.

Production of beet sugar in the United States from 1830 to 1899.

The following table, showing the production of beet sugar in the United States from 1830 to the present time, is taken from the Weekly Statistical Sugar Trade Journal for January 7, 1897, and January 5, 1899:

Production by years from 1830 to 1899.

1830	A few hundred pounds	1885	600 tons
1831–1837	None	1886	800 tons
1838–1839	1,300 pounds	1887	255 tons
1839–1862	None	1888	1,010 tons
1863–1871	300 to 500 tons per annum	1889	2,600 tons
1872	500 tons	1890	2,800 tons
1873	700 tons	1891	5,359 tons
1874–1877	Under 100 tons per annum	1892	12,091 tons
1878	200 tons	1893	20,453 tons
1879	1,200 tons	1894	20,443 tons
1880	500 tons	1895	30,000 tons
1881–1882	Less than 500 tons	1896	40,000 tons
1883	535 tons	1897–1898	41,347 tons
1884	953 tons	1898–1899	33,960 tons

Location of beet-sugar factories in the United States.

The following beet-sugar factories are now (February, 1899) in operation:

The Western Beet Sugar Company, Watsonville, Cal.; The Chino Valley Beet Sugar Company, Chino Valley, Cal.; The Alameda Sugar Company, Alvarado, Cal.; The Norfolk Beet Sugar Company, Norfolk, Nebr.; The Oxnard Beet Sugar Company, Grand Island, Nebr.; The Pecos Valley Beet Sugar Company, Eddy, N. Mex.; The Utah Sugar Company, Lehi, Utah; The Binghamton Beet Sugar Company, Binghamton, N. Y.; First New York Beet Sugar Company, Rome, N. Y.; Ogden Sugar Company, Ogden, Utah; Oregon Sugar Company, La Grande, Oreg.; Michigan Sugar Company, Bay City, Mich.; The Los Alamitos Sugar Company, Los Alamitos, Cal.; The California Beet Sugar and Refining Company, Crockett, Cal.; The Minnesota Sugar Company, St. Louis Park, Minn.; The Wisconsin Beet Sugar Company (in liquidation), Menominee Falls, Wis.

Factories are building or nearly completed at the following places:

Spreckels (Salinas), Cal. (Spreckels Sugar Company); Oxnard (Hueneme), Cal. (Pacific Beet Sugar Company); Santa Maria, Cal. (Union Sugar Company); Grand Junction, Colo. (Colorado Sugar Manufacturing Company); Pekin, Ill.

New factories are proposed at the following places:

Detroit, Mich. (Detroit Sugar Company); Peoria, Ill. (Illinois Sugar Company); Benton Harbor, Mich. (Wolverine Sugar Company); Monroe, Rochester, Caro, West Bay City, Alma, Grand Haven, Port Huron, Marine City, and Kalamazoo, Mich.; Lyons and Dunkirk, N. Y.; Springville, Utah; Newcastle, Pa.

There are also rumors of plants to be built at Irving, N. Y.; Toledo and Sandusky, Ohio; Corunna, Alpena, Mt. Clemens, and Tawas City, Mich.; Hamlet, Ind.; Omaha, Nebr.; Sioux Falls, S. Dak.; Fresno, Cal.

World's sugar crop.

The total sugar crops of the world for the past four years are given in the Weekly Statistical Sugar Trade Journal for January 19, 1899, as follows:

World's sugar crop.[1]

	1898-99.	1897-98.	1896-97.	1895-96.
	Tons.	*Tons.*	*Tons.*	*Tons.*
United States (beets, 33,960, 1898-99; 41,347, 1897-98; 40,000, 1896-97; 30,000, 1895-96)	268,960	351,794	322,009	267,720
Porto Rico	70,000	54,000	54,000	50,000
Canada (beets)	300	300	300	500
Cuba, crop	450,000	314,009	219,500	240,000
British West Indies:				
Trinidad, exports	50,000	53,000	53,000	58,000
Barbados, exports	47,000	53,500	58,249	47,800
Jamaica	27,000	30,000	30,000	30,000
Antigua and St. Kitts	22,000	25,000	29,000	24,000
French West Indies:				
Martinique, exports	32,000	35,000	35,000	35,000
Guadeloupe	40,000	45,000	45,000	45,000
Danish West Indies–St. Croix	12,000	13,000	13,058	8,000
Haiti and Santo Domingo	48,000	48,000	48,800	50,000
Lesser Antilles, not named above	8,000	8,000	8,000	8,000
Mexico, exports	2,000	2,000	2,000	2,000
Central America:				
Guatemala, crop	9,000	9,000	8,000	7,000
San Salvador, crop	4,000	4,000	3,000	2,000
Nicaragua, crop	1,500	1,500	500	500
Costa Rica, crop	500	500	200	200
South America:				
British Guiana (Demerara), exports	100,000	100,000	99,789	105,000
Dutch Guiana (Surinam), crop	6,000	6,000	6,000	6,000
Venezuela				
Peru, crop	75,000	70,000	70,000	68,000
Argentine Republic, crop	75,000	110,000	165,000	130,000
Brazil, crop	165,000	195,000	210,000	225,000
Total in America	1,513,260	1,528,603	1,480,405	1,409,720
Asia:				
British India, exports	50,000	50,000	50,000	50,000
Siam, crop	7,000	7,000	7,000	7,000
Java, exports	635,000	541,581	473,420	605,025
Japan (consumption 195,000 tons, mostly imported)				
Philippine Islands, exports	140,000	165,000	197,000	240,000
Cochin China	31,000	30,000	30,000	30,000
Total in Asia	863,000	793,581	757,420	932,025
Australia and Polynesia:				
Queensland	65,000	65,000	70,000	60,000
New South Wales	30,000	30,000	30,000	30,000
Hawaiian Islands	240,000	204,833	224,220	201,632
Fiji Islands, exports	30,000	30,000	30,000	30,000
Total in Australia and Polynesia	365,000	329,833	354,220	321,632
Africa:				
Egypt, crop	105,000	85,000	100,000	92,000
Mauritius and other British possessions	150,000	120,000	150,000	140,000
Réunion and other French possessions	45,000	45,000	48,000	44,700
Total in Africa	300,000	250,000	298,000	276,700
Europe—Spain	8,000	8,000	8,000	8,000
Total cane-sugar production	3,049,260	2,910,017	2,898,045	2,948,077
Total beet-sugar production (Licht)	4,790,000	4,825,529	4,916,586	4,285,429
Grand total cane and beet sugar production	7,839,260	7,735,546	7,814,631	7,233,506
Estimated increase in the world's production	103,714			

[1] In the above table is comprised the entire sugar production of all the countries of the world, including those crops which have heretofore been ignored in statistics. These figures include local consumptions of home production wherever known.

Production of beet sugar in Europe for four years, 1895 to 1899.

The quantities of sugar produced in Europe for four years, from 1895 to 1899, the last crop partially estimated, collated by Licht in his monthly circular and published in the Weekly Statistical Sugar Trade Journal of February 2, 1899, are as follows:

European sugar crop for four years, 1895 to 1899.

	1898-99.	1897-98.	1896-97.	1895-96.
	Tons.	*Tons.*	*Tons.*	*Tons.*
Germany	1,710,000	1,852,857	1,836,536	1,615,111
Austria	1,040,000	831,667	934,007	791,405
France	830,000	821,235	752,081	667,853
Russia	750,000	738,715	728,667	712,096
Belgium	220,000	265,397	288,009	235,795
Holland	150,000	125,658	174,206	106,829
Other countries	155,000	190,000	202,990	156,340
Total	4,855,000	4,825,529	4,916,496	4,285,429

Number of factories, yield of beets per acre, and yield of sugar in the principal beet-sugar countries of Europe.

Germany.—Number of factories in operation during 1895-96, 397; quantity of beets used, 11,672,816 tons; hectares cultivated, 376,669 (acres, 930,372); mean yield per hectare, 31,000 kilos (pounds per acre, 27,669); mean price of beets per metric ton, 17.70 marks (equal to $4.64 per ton of 2,000 pounds); yield of raw sugar (92 per cent) on weight of beets 13.11 per cent; average output of sugar per factory, 4,068 metric tons.

France.—Number of factories in operation during 1895-96, 356; quantity of beets used, 5,411,484 metric tons; yield of refined sugar on weight of beets, 10.97 per cent; hectares under cultivation, 204,715 (405,852 acres); yield of beets in metric tons per acre, nearly 10.5; average output of sugar per factory, 1,876 tons.

Austria-Hungary.—Number of factories in operation in 1895-96, 216; quantity of beets used, 5,760,000 metric tons; yield of raw sugar (92 per cent) on weight of beets, 13.5 per cent; average output of sugar for each factory, 3,663 tons.

Russia.—Number of factories in operation during 1895-96, 277; quantity of beets used, 5,311,888 metric tons; per cent of sugar in beets, 15.71; average output of sugar for each factory, 2,828 tons.

Consumption of sugar in the United States.

The first of the following tables shows the consumption of sugar in the United States for each of the years 1896, 1897, and 1898, with a detailed statement of the origin of the sugar consumed, and the second is a statement of the consumption in the United States from 1881 to 1898, inclusive. The tables are taken from the Weekly Statistical Sugar Trade Journal of January 5, 1899.

Consumption of sugar in the United States during the years 1896, 1897, and 1898.

Source of sugar supply.	1898.	1897.	1896.
	Tons.	*Tons.*	*Tons.*
Meltings of the four ports	1,502.000	1,597,000	1,508,000
Of which were domestic from Louisiana crop	6,443	9,662	1,411
	1,495,557	1,587,338	1,506,589
Meltings of foreign sugar through New Orleans	9,431	59,793	30,520
Foreign refined through Galveston	23	1,060	2,000
Total	1,505,011	1,648,191	1,539,109
Export of raw sugar from Atlantic ports	1,450	14,955	11,500
Export of refined sugar from Atlantic ports	4,192	2,516	3,100
Total exports to be deducted	5,642	17,471	14,600
Consumption of foreign sugar through Atlantic ports	1,499,369	1,630,720	1,524,509
Consumption of foreign sugar through San Francisco	139,668	129,887	146,454
Total consumption of foreign sugar	1,639,037	1,760,607	1,670,963
Louisiana crop consumed during the year	310,447	282,009	237,720
Texas crop consumed during the year	7,000	7,000	5,500
Total consumption of domestic cane sugar	317,447	289,009	243,220
California beet-sugar crop	16,700	32,417	27,300
Nebraska beet-sugar crop	4,700	6,460	8,000
Utah beet-sugar crop	5,700	1,570	4,700
Oregon beet-sugar crop	660	.....	.....
New Mexico beet-sugar crop	1,000	525	.....
Minnesota beet-sugar crop	1,100	.....	.....
Michigan beet-sugar crop	2,500	.....	.....
New York beet-sugar crop	1,600	375	.....
Consumption of domestic beet sugar	33,960	41,347	40,000
Consumption of sorghum sugar	300	300	300
Consumption of maple sugar	5,000	5,000	5,000
Molasses sugar made in United States from foreign molasses	1,700	150	603
	1,997,444	2,096,413	1,960,086
Add undistributed refined brought over from previous year	75,000	50,000	30,000
	2,072,444	2,146,413	1,990,086
Deduct undistributed refined carried over to next year	25,000	75,000	50,000
Total consumption of all sugar	2,047,444	2,071,413	1,940,086

Consumption per capita is 61.1 pounds in 1898, 63.7 pounds in 1897, 60.9 pounds in 1896, 64.23 pounds in 1895, 66.64 pounds in 1894, 63.83 pounds in 1893, 63.76 pounds in 1892, 67.46 pounds in 1891, 54.56 pounds in 1890, 52.64 pounds in 1889, 54.23 pounds in 1888, 53.11 pounds in 1887, 52.55 pounds in 1886, 49.95 pounds in 1885, and 51 pounds in 1884.

Consumption of sugar in the United States during the years 1881 to 1898, inclusive.

Year.	Total consumption of United States.	Increase(+) or decrease (—).	Year.	Total consumption of United States.	Increase(+) or decrease (—).
	Tons.	*Per cent.*		*Tons.*	*Per cent.*
1898	2,047,444	— 1.16	1889	1,439,701	— 1.21
1897	2,071,413	+ 6.90	1888	1,457,264	+ 4.62
1896	1,940,086	+ 0.53	1887	1,392,909	+ 2.73
1895	1,949,744	— 3.27	1886	1,355,809	+ 8.11
1894	2,012,714	+ 5.08	1885	1,254,116	+ 0.14
1893	1,905,862	+ 2.83	1884	1,252,366	+ 7.0
1892	1,853,370	— 1.102	1883	1,170,375	+10.3
1891	1,872,400	+22.96	1882	1,061,220	+ 6.8
1890	1,522,731	+ 5.80	1881	993,532	.....

Increase for seventeen years, 106.07 per cent, or 6.24 per cent per annum.

Consumption of sugar per head.

The following table, taken from the Weekly Statistical Sugar Trade Journal, shows the consumption of sugar in pounds per head for all the countries of Europe and for the United States for four years from 1891–92 to 1894–95:

Consumption of sugar for the United States and all the countries of Europe for 1891–92 to 1894–95.

Country.	Population 1895.	1894–95.	1893–94.	1892–93.	1891–92.
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*
Germany	51,650,000	26.78	26.71	22.90	23.56
Austria	43,456,000	19.81	16.57	17.20	16.05
France	38,800,000	30.61	27.80	27.86	30.46
Russia	100,239,000	10.94	11.06	10.94	10.34
Holland	4,732,000	31.30	25.55	22.90	26.88
Belgium	6,325,000	22.50	21.73	21.09	21.29
Denmark	2,300,000	45.41	42.96	43.53	43.63
Sweden and Norway	6,873,000	24.95	24.82	23.64	24.14
Italy	30,724,000	6.65	7.07	7.00	7.18
Roumania	5,800,000	4.03	4.07	4.53	3.90
Spain	17,650,000	13.68	12.47	12.38	11.06
Portugal and Madeira	5,082,000	12.92	13.09	12.51	12.43
England	38,927,000	86.09	84.78	77.40	80.73
Bulgaria	3,310,000	8.88	7.14	6.07	5.16
Greece	2,235,000	6.26	7.29	7.38	8.62
Servia	2,256,000	4.01	4.25	4.22	3.81
Turkey	21,983,000	7.65	7.25	7.64	9.30
Switzerland	2,895,000	44.66	42.30	31.62	31.30
Europe	385,177,000	25.64	23.25	22.02	22.64
United States	69,753,000	62.60	66.64	63.83	63.76
Total	454,930,000	31.07	29.33	28.20	29.00

Rate of increase in consumption.

The rate of increase in the consumption of sugar for twenty-three years for the principal sugar-consuming countries is as follows:[1]

Rate of increase in the consumption of sugar in five principal countries.

Country.	Per cent in 23 years.	Per cent a year.
France	142	6.18
Germany	159	6.91
Austria	107	4.65
England	90	3.50
United States	278	12.10

[1] Zeit. des Vereins f. Rubenzuckerind., June 1896, S. 248.

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